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A Preliminary Summary of

Progress and Plans //

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CITRUS AND SUBTROPICAL FRUIT RESEARCH  
of the United States Department of Agriculture  
and  
in cooperation with  
State Agricultural Experiment Stations, +3a

Prepared for the Department's  
CITRUS AND SUBTROPICAL FRUIT RESEARCH AND MARKETING ADVISORY COMMITTEE

for its 16th Annual Meeting  
Washington, D. C.  
November 2-6, 1959

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C & R-PREP.

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• This progress report is primarily a tool for use by advisory com- •  
• mittee members in developing recommendations for present and future •  
• research programs and by USDA administrators for developing, coordi- •  
• nating, and evaluating research plans. Included in it are summaries •  
• of research done during the past year. Some are tentative results •  
• that have not been tested sufficiently to justify general release. •  
• Such findings, when adequately confirmed, will be released promptly •  
• through established channels. Because of this, the report is not •  
• intended for publication and should not be referred to in literature •  
• citations. Copies are distributed only to advisory committee members, •  
• research administrators, and others having special interest in the •  
• development of public agricultural research programs. •

• The report also lists publications of research results issued •  
• during the year. Current agricultural research findings are also •  
• reported in the monthly USDA publications, "Agricultural Research" •  
• and "Agricultural Marketing." •

• .....

## FUNCTIONS OF ADVISORY COMMITTEES

The Citrus and Subtropical Fruit Advisory Committee is one of twenty-five commodity and functional committees of the U. S. Department of Agriculture established pursuant to Title III of the Research and Marketing Act of 1946. Functions of the members of these committees include:

1. Acquainting themselves with the problems of producers, processors, distributors, and consumers, and presenting them for committee consideration.
2. Reviewing the current research and marketing service programs of the Department and recommending adjustments, including terminations, in the current program in order that available funds, personnel, and facilities will be used on problems of greatest importance.
3. Recommending new work or expansion of current work and indicating relative priority of such recommendations, when the current program is insufficient to develop solutions for important problems.
4. Developing a better understanding of the nature and value of the agricultural research program, explaining it to interested groups and organizations and encouraging the wider and more rapid applications of the findings of research.

The committees perform an important function in advising with respect to the development of the Department's research and marketing service programs. However, committee members recognize that the development of budgets and the implementation and administration of research and marketing programs are responsibilities of the Department.

A progress report similar to this one is prepared for each committee. The areas of the other twenty-four committees are:

Cotton and Cottonseed	Oilseeds and Peanut
Dairy	Potato
Deciduous Fruit and Tree Nut	Poultry
Economics	Refrigerated and Frozen Products
Farm Equipment and Structures	Rice
Feed and Forage	Seed
Food and Nutrition	Sheep and Wool
Food Distribution	Soils, Water and Fertilizer
Forestry	Sugar
Grain	Tobacco
Home Economics	Transportation
Livestock	Vegetable

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# CODES TO DESIGNATE UNITS CONDUCTING RESEARCH

## AGRICULTURAL RESEARCH SERVICE (ARS)

### Farm Research Divisions

AE	.....	Agricultural Engineering
ADP	.....	Animal Disease and Parasite
AH	.....	Animal Husbandry
CR	.....	Crops
ENT	.....	Entomology
FE	.....	Farm Economics
SWC	.....	Soil and Water Conservation

### Utilization Research and Development Divisions

EU	.....	Eastern
NU	.....	Northern
SU	.....	Southern
WU	.....	Western

### Home Economics Research Divisions

CH	.....	Clothing and Housing
HHE	.....	Household Economics
HN	.....	Human Nutrition

## AGRICULTURAL MARKETING SERVICE (AMS)

### Marketing Research and Statistics Divisions

AEC	.....	Agricultural Economics
AES	.....	Agricultural Estimates
		Marketing Research Branches (MRD)
BS	.....	Biological Sciences
MD	.....	Market Development
OC	.....	Market Organization and Costs
TF	.....	Transportation and Facilities

FCS .. FARMERS COOPERATIVE SERVICE

FAS .. FOREIGN AGRICULTURAL SERVICE

## FOREST SERVICE (FS)

### Forest Research Divisions

FDR	.....	Forest Disease
FER	.....	Forest Economics
FFR	.....	Forest Fire
FIR	.....	Forest Insect
FPR	.....	Forest Products
RMR	.....	Range Management and Wildlife Habitat
WMR	.....	Watershed Management

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## I. FARM RESEARCH

## A. Breeding and Genetics

## PLANT INTRODUCTION AND DEVELOPMENT

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Problem: As possible new varieties and as germ plasm for the use of breeders, there is need for a complete collection of the wild and cultivated forms of citrus and subtropical fruits from all parts of the world.

Program: A continuing long-term program of foreign exploration, collection, introduction, quarantine, preliminary evaluation, and distribution carried on at Glenn Dale, Maryland, Miami and Orlando, Florida, and involving two Federal professional man-years annually.

Progress: The following 60 introductions of citrus materials were made during the year:

<u>Species</u>	<u>Number of introductions</u>	<u>Source</u>
Citrus assamensis	1	India
C. aurantifolia	1	Brazil
C. aurantium	7	Brazil
	1	India
C. aurantium var myritifolia	2	Brazil
C. crenatifolia	1	Ceylon
Citrus grandis	2	Brazil
	2	India
C. hystrix	1	Philippines
	1	Morocco
C. hy (Chironja)	5	Puerto Rico
C. jambhiri	2	India
C. karna	1	India
C. latipes	2	India
C. limon	7	Brazil
	2	India
C. macroptera	1	India
C. medica	3	Brazil
C. reticulata	1	Brazil
	2	India
	1	Hawaii
C. sinensis	6	Brazil
	1	New Zealand
	1	India
C. sinensis x Poncirus trifoliata	3	Argentina
Undetermined C. sp.	2	Venezuela
	1	Algeria

Most of the new introductions were secured as seeds since they can be sent, after treatment, into any of the States where citrus is grown. A better understanding of the nucellar seedlings produced by most citrus makes introductions as seeds even more desirable than budwood.

Many of the introduced seed lots were requested for the screening program for resistance to the burrowing nematode. Additional propagations of the one surviving specimen of *Citropsis gilletinana* at the U. S. Plant Introduction Station, Miami, Florida, has been furnished the Florida station at Lake Alfred. Additional collections have been requested from the Belgian Congo. Citrus investigators working in California have requested collections from the Philippines of species tolerant to high salt and boron and iron chlorosis.

Fifty-eight budded plants, six rooted cuttings and three budsticks of 36 citrus introductions were sent to the California Experiment Station at Riverside for virus indexing. The introductions of citrus and related genera which have been sent to Riverside for indexing now total 103. There have been six shipments since the program started in November 1954.

The large collection of avocados maintained at the U. S. Plant Introduction Station, Miami, Florida is being screened for resistance to avocado root rot, caused by *Phytophthora cinnamomi* in a cooperative project between the New Crops Research Branch and the University of California. Seeds of the different introductions are sent from Florida to the University of California, Riverside, and are screened for root rot resistance. The survivors from these tests will be retained for additional tests and for observation.

Plans: Exploration for additional citrus and subtropical fruit stocks will be undertaken upon recommendation from advisory committees or from related research agencies.

## BREEDING AND VARIETY EVALUATION

CR

Problem: All sectors of the citrus industry are in need of new varieties of productive, high quality citrus that will lengthen the season of production for fresh and processing purposes, a succession of loose-skinned fruit of tangerine or tangelo type, cold hardy lemons, early maturing grapefruit, and a late red grapefruit that does not fade in color. The date industry is also in need of better quality varieties adapted to U. S. conditions.

Program: A continuous long-range program on citrus breeding is being conducted by the Department on a regional basis at Indio and Brawley, California; Weslaco, Texas; and Orlando, Florida; in cooperation with the State agricultural stations, Rio Farms, Inc., Edcouch, Texas, and the Florida Citrus Research Foundation. This work involves about three Federal professional man-years annually.

A continuous long-range date breeding program is carried on at Indio and Brawley, California, involving less than one professional man-year.

Progress: Citrus breeding in Florida. Monoembryonic varieties that could be expected to produce high percentages of hybrids were selected for crossing in the 1959 blooming season. Because of heavy rains during the blooming season, emasculation of blossoms and hand pollination was difficult and only a small number of fruit was set from this work.

About 6,000 seedlings from 48 new crosses made in 1958 were grown in the greenhouse during 1959. Parents for these crosses were chosen to combine hardiness, high internal and external color, large size, earliness, fine flavor, and seedlessness. Progeny from 15 crosses yielded data on polyembryony that will aid in the future selection of female parents.

Two additional selections made from the 1942 crosses during 1958 on the basis of flavor and appearance and are being propagated. They are both of the tangerine type. This makes a total of 61 selections worthy of further testing that have been made from the 1942 crosses.

New citrus varieties from Florida. Three of the selections made from the 1942 crosses will be released to the industry this year. These varieties are to be described and named at the October meeting of the Florida State Horticultural Society and released to the citrus industry as soon as the tristeza-free budwood is ready. These are hybrids of Clementine x Orlando tangelo. Two look like tangerines and are larger than the ordinary Dancy tangerine, 6 to 8 weeks earlier in reaching maturity, much redder in peel color, and sweeter. The other resembles a loose-skinned orange or tangelo more than it does a tangerine. It is also early maturing, although it doesn't reach a high external color as early as the other two. Preliminary rootstock trials with these new introductions show that they should not be propagated on Rough lemon. The quality of the fruit is high when the tree is budded to Rusk citrange and Cleopatra mandarin. Trials with other rootstocks are now in progress.

Citrus breeding in California. In 1959 about 50 loose-skinned mandarin types of citrus were selected and propagated for second test. Several grapefruit-like shaddock hybrids of high quality were selected for second trial and for further hybridizing. Seedlings were crosses of Messina, Eureka, and Lisbon lemons with Meyer lemon are coming into bearing and being evaluated and selections made for further tests.

Seedlings from crosses designed to produce early sweet oranges were planted in the field

Back-crosses of tangelos to Marsh grapefruit made with the object of improving cold hardiness of grapefruit were failures. Extensive hybridization was carried out with the object of producing loose-skinned oranges and early oranges.



Citrus evaluation in Texas. The Texas program consists not in producing crosses, but in growing and testing crosses made at Orlando, Florida, and Indio, California. During the past year, budwood of 59 hybrids and eight nucellars from Indio was planted in Texas. Some of these introductions are promising selections not previously available in Texas; others are expected to provide information on types of hybrids needed in an expanded breeding program for Texas.

Land for citrus breeding in Texas and California. An agreement has been reached with Rio Farms, Inc., Edcouch, Texas, to allot the USDA immediately ten acres for orchard testing of new hybrids now available. As more hybrids become available for testing, up to 40 acres of land will be provided. In Florida, the Florida Citrus Research Foundation acquired a 500-acre tract ten miles south of Leesburg to be used for citrus breeding and variety development. The tract of land has been purchased by the Foundation and a portion has been assigned to the USDA for use under terms of a cooperative agreement.

Plans: Study and evaluation of seedlings will be continued, and promising ones propagated on standard stocks for second trial. The acquisition of new land both in Texas and Florida will enable the fruiting out of seedlings and the growing of promising ones on rootstocks for a second trial on an expanded and extensive basis.

In Florida, the new hybrid selections will be crossed to seedless oranges in an attempt to reduce seediness. Temple will be crossed with selected orange and tangelo varieties to produce high quality round oranges. Crosses will be made between monoembryonic mandarin-grapefruit hybrids and grapefruit varieties to obtain new early maturing, high-quality grapefruit.

In California, hybridization of loose-skinned types and of early oranges and back-crossing of grapefruit with tangelos and pollinating Red Shaddock with grapefruit will be continued.

Because few hybrid seedlings are obtained in crosses of most rootstocks varieties, extensive crossing will be continued in an effort to obtain large populations. Testing will be continued as seedlings are available in an effort to find more desirable rootstocks.

Publications: Problems and Progress in Breeding Citrus in Florida.  
Philip C. Reece. Rio Grande Valley Hort. Soc. 13:18-21. 1959.

## ROOTSTOCK BREEDING AND EVALUATION

CR

Problem: Rootstocks to which a variety is budded affect the quality and yield of citrus and other subtropical fruits. More information is needed on the best rootstock-scion combinations for different soils and climatic conditions. Rootstocks now available and those to be produced in the breeding program need to be evaluated for disease, insect, and nematode susceptibility, cold hardiness, tolerance to salts and wet soils, and for their effect on fruit yield and quality.

Program: A continuing long-term program involving pathological nematological and physiological laboratory and field studies at Indio, California; Orlando, Florida; and Weslaco, Texas, in cooperation with Rio Farms, Inc., Edcouch, Texas, the State Experiment Stations of Texas, Florida, and California, and commercial citrus growers; involving two Federal professional man-years annually.

Progress: Tolerance of rootstocks to nematodes. The USDA in cooperation with the Citrus Experiment Station of the University of Florida has continued to screen citrus species, varieties, and relatives for resistance to attack by the burrowing nematode, *Radopholus similis* (Cobb) Thorne. About 300 varieties, species, and relatives were screened during the year, none of which showed sufficient resistance or tolerance to the burrowing nematode to be tested in the field.

The Citrus Experiment Station of the University of Florida collected seed of some 500 named varieties not found in Florida from California, Arizona, and Texas. The University of California at Riverside, and the USDA in Texas and Arizona cooperated in this venture. These seeds have been germinated and are now under test. Seed of 31 varieties, species, and relatives from Brazil have also been tested and found susceptible. To date, Rough lemon B, Sanguina Grosse Ronde, Pineapple RS-156, Clone X and Carrizo citrange have been selected as promising enough to be field tested. Seedlings of the first four have been started in the Davenport nursery of the University of Florida Citrus Experiment Station and will be ready for budding this fall. No seed is available from Clone X. A comparison of the growth and characteristics of Valencia and Pineapple orange budded on Rough lemon and Sanguina Grosse Ronde growing in clean and nematode-infested soil has been under way for the past year under greenhouse conditions. These plants will be transferred to the field after one more year of greenhouse observations. Evidence has now been secured indicating that Carrizo citrange is more tolerant to attack by the burrowing nematode than Troyer citrange. Neither of these plants grow as well as Sanguina Grosse Ronde in the presence of the burrowing nematode.

Citrus rootstock investigations in Florida. An old-line planting of Parson Brown orange on various rootstocks on deep Lakeland sand characteristic of much of the central citrus belt is now 17 years old. The trees on Rough lemon have consistently produced more fruit than trees on other rootstocks but the differences have become noticeably less during recent

years. The nearest competitor to the Rough lemon rootstock is the Cleopatra mandarin. Though producing a slightly larger tree, it has yielded 34 percent less fruit than the Rough lemon. Sweet orange rootstocks trail the Cleopatra mandarin slightly in both yield and tree size.

On various rootstocks of the same age and at the same location, the advantage in yield of Valencia on Rough lemon as compared with other rootstocks was much greater than with the Parson Brown variety. The nearest competitor to the Rough lemon rootstock for the Valencia variety was the sweet orange rootstock which produced 60 percent less fruit than on Rough lemon. Valencia on the Cleopatra mandarin rootstock were slightly less productive. There was almost no difference in tree size between Valencia on Rough lemon, sweet orange and Cleopatra mandarin after 16 years. To date, old-line Valencia on Rough lemon rootstock have out-yielded trees on any other rootstock but have produced the lowest quality fruit. Even with this low quality the larger yield of Valencia on Rough lemon adds up to more pounds solids per acre than on any other rootstock.

During the past year, six new rootstock test orchards using virus-free nucellar tops were planted with commercial citrus growers. The scion varieties include Valencia orange, Pineapple orange, and Marsh grapefruit. The rootstocks include varieties which appeared to have merit in the earlier old-line experiments plus a large number of citrange and sweet orange varieties. A better evaluation of the influence of rootstock should be possible in these plants because they will not be complicated by the presence of viruses which are known to be responsible for the poor performance of some rootstock varieties.

Citrus rootstock investigations in Texas. A nucellar Red Blush rootstock planting made at Rio Farms in January 1956 set a small crop of fruit on many of the trees in the spring of 1959. The production of fruit is still too light to determine significant differences in rootstocks but will be followed for several years.

In a rootstock orchard planted in 1950, old-line Red Blush grapefruit tops on 13 rootstocks tolerant to xyloporosis and exocortis, produced as much or more fruit than on sour orange. This strain on Precoc sweet orange, Citrumelo 4475 and Rough lemon produced considerably more fruit than on sour orange, Cleopatra mandarin and others.

Unusually heavy rains during September and October 1958 created a high water table in the two rootstock orchards at Rio Farms. Yellow-vein chlorosis associated with the high water table was generally more severe on red grapefruit trees affected with virus diseases, whereas it did not occur on virus-free young-line trees or on virus-infected trees on virus tolerant rootstocks. In another better drained rootstock orchard at Weslaco, Texas, yellow-vein chlorosis occurred on red grapefruit tops on certain rootstocks and was associated with cool weather in early December. Again the yellow-vein chlorosis was generally more severe on the trees virus-expressing rootstocks than on virus tolerant rootstocks.



Salt and boron tolerance of young-line and Red Blush grapefruit on various rootstocks in trees. Chloride accumulation was less in leaves of young-line (nucellar) trees than in old-line trees but young-line trees were larger and thus had a larger leaf area. Salt treatments decreased growth of both young-line and old-line trees in direct proportion to the concentration of the salt in irrigation water; the decreased growth was approximately the same for both young-line and old-line trees. Trees on certain rootstocks accumulated chloride but not boron and vice versa. The Cleopatra, Timkat, and Sunki mandarin rootstocks excluded chloride and boron; and Citrus macrophylla excluded boron but accumulated chloride. None of the rootstocks in these trials appeared to be able to exclude both chloride and boron.

Avocado rootstock plantings in Texas. A test planting comprising 12 trees each of 12 scion-rootstock combinations was set out at Rio Farms.

Rootstock testing in California.  $F_1$  seedlings from Rangpur lime crosses were being tested for salt tolerance and striking differences were observed. Seedlings from 20 crosses made in 1958 were planted in the field. About 25 crosses were made between various species and varieties in 1959 for subsequent testing as rootstocks.

Screening rootstocks in California. The screening program for Phytophthora root rot resistance involved the testing of 8,865 more seedlings of 167 citrus species, varieties, hybrids, and citrus relatives. There were 3,168 seedling survivors; this high number reflects the testing of many relatively resistant kinds of citrus, including varieties or hybrids of trifoliolate oranges, citranges, citrumelos, shaddocks, and species of Severinia and Microcitrus.

The survivors from the phytophthora root rot resistance test reported above were then planted in the nursery for study of their tolerance to high lime soil conditions. Great differences are already evident.

Plans: The citrus rootstock research will be carried on at approximately the same level as heretofore with more emphasis on cold hardiness and increased studies with hybrids produced directly for use as rootstocks.

Publications: Virus-free Seedling-line and Old-Line Selections of Citrus Varieties in Texas. E. O. Olson, W. C. Cooper, and A. V. Shull. Jour. Rio Grande Valley Hort. Soc. 13: 22-26. 1959.

Experimental Control in Citrus Trees of Iron Chlorosis Associated with the Virus Disease Cachexia and High Soil Salinity by Applications of Iron Chelate. W. C. Cooper and A. Peynado. Jour. Rio Grande Valley Hort. Soc. 13:75-80. 1959.

Chloride and Boron Tolerance of Young-line Citrus Trees on Various Rootstocks. W. C. Cooper and A. Peynado. Jour. Rio Grande Valley Hort. Soc. 13:89-96. 1959.

Yellow-vein Chlorosis of Old-line and Young-line Red Grapefruit on Various Rootstocks. W. C. Cooper, E. O. Olson, and A. V. Shull. Jour. Rio Grande Valley Hort. Soc. 13:81-88. 1959.

Effect of Gibberellic Acid on Growth and Dormancy in Citrus. W. C. Cooper and A. Peynado. Proc. ASHH 72:284-289. 1958.

Response of Grapefruit on Two Rootstocks to Calcium Additions to High-Sodium Boron-contaminated and Saline Water. W. C. Cooper, A. Peynado and E. O. Olson. Soil Science 86:180-189. 1958.

Effects of Sub-freezing Temperatures on the Viability of Citrus Seeds. George E. Horanic and F. E. Gardner, Fla. State Hort. Soc. 71:79-81. 1958.

Influence of Various Rootstocks on the Cold Resistance of the Scion Variety of Citrus. F. E. Gardner and G. E. Horanic. Fla. State Hort. Soc. 71:81-86.

## B. Physiology and Nutrition

### PHYSIOLOGY AND NUTRITION OF CITRUS AND DATES

CR

Problem: Kinds and varieties of citrus and subtropical fruits require different nutritional levels under varying climatic and soil conditions and respond differently to growth regulating compounds and physiological conditions. Information is needed on such factors as the effect of different sources and rates of nitrogen and different rates of potash on the production and fruit quality of grapefruit, the feasibility of soil applications of copper zinc and manganese, and the effect of different amounts of nitrogen on the production and quality of Deglet Noor dates.

Program: A long-range program of laboratory and field type physiological and nutritional studies with citrus and dates is carried on at Orlando, Florida, Weslaco, Texas, and Indio, California, in cooperation with commercial growers. The work involves about three professional man-years.

Progress: Nitrogen source on Florida grapefruit. Calcium nitrate, ammonium nitrate and ammonium sulfate -- each at 120 and 240 pounds of nitrogen per acre per year -- were compared at two lime levels on Marsh grapefruit. With sufficient dolomitic liming to control the soil pH at above 6.0, the nitrogen sources have been indistinguishable in their effects on growth production, and fruit quality. At pH of about 5.0, however, the trees are less thrifty on both sources of ammonia nitrogen and the yields have been depressed by as much as 25 percent where the high rate of ammonium sulfate has been used. Yields have not been increased by the higher rate of nitrogen fertilization. These results were obtained in good groves yielding an average of 500 boxes per acre or more for the past six years. The results are in harmony with those found in sand and solution culture studies at this laboratory in recent years which show that citrus can utilize nitrogen from any of the usual sources but that citrus roots are very sensitive to even mild excesses of acidity. The present field experiment shows also that grapefruit require less nitrogen than has been recommended heretofore and on this basis the official recommendation for the industry is being changed in 1959 to call for lowered rates of fertilizer for grapefruit.

Potash level on grapefruit. A companion experiment on the effect of different rates of potash is being carried on in the same orchard as the nitrogen source experiment. Rates of 30, 120, and 300 lb. of  $K_2O$  annually per acre have been applied for the past six years. The low rate has led to the production of small-sized fruit and a gradual decrease in production. The fruit on such trees is the first to reach maturity in the fall and is of lower acidity but is inclined to drop from the tree when held until January. Fruit produced at the two higher levels of  $K_2O$  are virtually indistinguishable except for the greater acidity at the highest level.

There are two striking differences between grapefruit and oranges in regard to potash level. In the first place, Valencia oranges show a steady increase in fruit size as the potash supply increases over a very wide range. Grapefruit, on the other hand, show a tendency for small size at very low potash levels but the effect of high levels on the size seems to be absent. In the second place, increased potash results in a steady lowering of the sugars in the juice of oranges but has virtually no effect on the sugars in the juice of grapefruit. These differences in varietal response show that there is a high degree of specificity in some nutritional responses and caution should be used in attempting to generalize too broadly on the effects of fertilization.

From the practical standpoint, the 120 pound rate of  $K_2O$  has been adequate to give maximum size and yield of grapefruit. Thus, 120 pounds of both nitrogen and  $K_2O$  per acre for 500-box production appears to be ample and amounts larger than this are extravagant. General practice for the past 20 years has been to use nearly double these amounts.

Other work on citrus nutrition. The use of anhydrous ammonia by soil injection is under trial both in regard to rate and placement but it will require several years to determine the feasibility of using this cheap source of nitrogen.



Experiments with soil applications of copper, zinc, and manganese show considerable promise of one initial application to the soil lasting many years. Tests on young-tree fertilization are being continued to gain as much information as possible on rates, times of application, and essential ingredients in the mixture. Results to date show that young trees are usually fed overzealously, both in regard to amount and number of feedings per year.

Cold hardiness research. The phytotron and a biochemical laboratory at the U. S. Fruit, Vegetable, Soil and Water Research Laboratory, Weslaco, Texas, were completed during 1959. This will provide modern laboratory facilities and controlled temperature, light, and humidity conditions for fundamental studies on the control of dormancy and cold hardiness in citrus. The facilities will also lend themselves to a biochemical study of what happens to the citrus tree when it is hardened and when it freezes. In addition to the above-mentioned physical facilities, a biochemical physiologist has been added to the Texas staff.

A portable tree freezer, large enough to cover a mature bearing tree, was also constructed during 1959 and will enable taking cold hardiness work to the field with more precision than is obtained from observations made on natural freezes. Nucellar trees of various scion-rootstock combinations and inoculated with various viruses are being grown in the field preparatory to testing for cold hardiness with the tree freezer.

During the year a study was started on the effect of climate on growth and dormancy with work at Orlando, Florida; Weslaco, Texas; Phoenix, Arizona; and Riverside, California.

Nitrogen fertilizer on dates. Heavy nitrogen fertilization lowered fruit quality but greatly increased yields of marketable grades of fruit. With the application of 14 or 10 feet of water per year, the leaching of salt was adequate; with only six feet per year, 22 tons of salt per acre accumulated in the top 16 feet of soil and was beginning to limit tree growth and yield.

Gibberellic acid on dates. Gibberellic acid applied to undeveloped date fruit stimulated elongation but usually at the expense of thickness and without much change in time of ripening or any significant effect on weight; the higher concentrations used increased the amount of shrivel and checking. Gibberellic acid applied to inflorescences or fruitstalks in early stages of growth increased the length of the fruitstalks but resulted in an undesirable twisting or spiraling.

Plans: The citrus mineral nutrition research will be carried on at approximately the same level as heretofore.

In the date research program, a survey will be made in growers' gardens of salt accumulation in the soil in relation to soil type, depth to water table, and amount of water applied.

The cold hardiness research on citrus will be accelerated with vigor at Weslaco, Texas.

The study of the effect of climate on growth and dormancy in citrus will be continued.

Publications: Relation of Fertilization to Winter Cold Injury of Citrus. P. F. Smith and G. K. Rasmussen. Proc. Fla. State Hort. Soc. 71:170-175. 1958.

Effects of H-ion Concentration on Growth of Pineapple Orange Seedlings in Alternate Solution and Water Cultures. G. K. Rasmussen and P. F. Smith. Proc. Amer. Soc. Hort. Sci. 73:242-247. 1959.

### C. Cultural Practices

#### IRRIGATION AND THINNING OF DATES

CR

Problem: It is important in the irrigation management of date gardens to know whether varying the time between irrigations affects the root distribution of the palm. Likewise it is important to know the effect of thinning on the size of the individual fruit and on the total yield.

Program: A continuing program of relatively short duration studies of an applied nature at Indio, California, and vicinity in cooperation with date garden owners, involving about one Federal professional man-year annually.

Progress: Irrigation trial on Khadrawy dates. In the last year of a six-year trial, root samples were taken to a depth of 23 feet on Khadrawy date palm plots that were irrigated most frequently and least frequently. Root distribution was nearly the same in all plots; density of root population was greatest in silt or clay layers and least in coarse sand, and generally was greatest at the five- to seven-foot depth.

Thinning trials with Deglet Noor dates. As the number of bunches increased, fruit size decreased but yield of fruit increased. The amount of marketable fruit produced by trees thinned to carry a crop load of 80 percent was about the same as on unthinned palms but was greater than that produced on palms thinned to crop loads of 40 and 50 percent.

Plans: The block of palms used in the irrigation experiment will be used in a nitrogen fertilizer test to determine the relation of rate on yield of Khadrawy palms.

## D. Disease and Nematode Control

## DISEASE CONTROL

CR

Problem: Fungus and virus diseases of citrus trees cause substantial losses to citrus wherever grown in the United States. The old spraying and dusting control measures used for fungus diseases are not effective on virus diseases. Since plants propagated vegetatively, once infected, carry the virus from then on, methods of control require such measures as virus indexing programs and foundation plantings of clean budwood. The spreading decline disease of citrus trees in Florida is generally attributed to the burrowing nematode, but recent findings indicate that other factors such as certain soil microflora may be involved in a complex with the nematode. New research is needed to resolve these problems and to find better methods of control.

Program: The program involves continued fundamental and applied research on diseases affecting citrus and other subtropical fruits conducted by the Department on a regional basis in cooperation with the State Agricultural Experiment Stations in California, Arizona, Texas, and Florida, and at Federal laboratories at Indio, California, Weslaco, Texas, and Orlando, Florida; utilizing about six Federal professional man-years annually.

Progress: Tristeza virus strain investigations in Florida. The mild strain of tristeza virus was not altered by infection and recovery from Key lime, Eureka lemon, sour orange and grapefruit seedlings. The strong and severe strains were latered to some degree by passage through sour orange, Eureka lemon, and grapefruit but not altered by passage through Key lime. Evidence was obtained that variable amounts of stem pitting symptoms are due to specific host responses to tristeza virus strain mixtures. The results of these tests help to explain the range in tristeza virus symptoms obtained from miscellaneous field tree collections.

Heat chamber studies. As previously reported, tristeza-virus-free budwood can be secured by exposure of infected potted plants in a heat chamber and propagation from the young virus-free tissues which grew while the plant was in the chamber. Therefore, a study of the minimum safe exposure time and the minimum effective temperature become necessary. Analysis of 269 propagations from heated treated Key lime, sweet oranges and mandarin hybrids showed 17 percent were virus-free after exposure of 40 days and up to 360 days was required to obtain 100 percent free. It has been demonstrated that inactivation of the tristeza virus occurs in the young shoots produced on plants in a heat chamber even though their roots, outside of the heat chamber are at temperatures 10 to 15° F. cooler than the branches.

An attempt to eliminate the xyloporosis (cachexia) and exocortis viruses in Temple orange and Persian lime is under way. Infected plants have been exposed for periods of 45, 75, 112, 225, 300, and 370 days and propagations from these are now being indexed. The long period of one to six years required for diagnosis of xyloporosis and exocortis virus on indicator plants greatly delays results.



Inactivation of tristeza in valuable citrus hybrids. The discovery of tristeza in many of the field-grown mandarin hybrids developed in the citrus breeding program has made it necessary to withhold introduction until virus free stocks could be obtained. Testing 42 of the new hybrids revealed that 15 were infected with tristeza virus. Through heat treatment, tristeza-virus-free propagations have been obtained from all of these. It thus appears that heat therapy will be a valuable tool for freeing propagating wood at least from some viruses.

Tristeza effect on rootstocks in Texas. To determine the effect of tristeza virus on sweet orange on various rootstocks under Texas conditions, one-year-old nucellar Valencia trees on 11 different varieties of sour orange and on Troyer citrange, Rangpur lime, Ponkan Mandarin, Morton citrange and Cleopatra mandarin rootstocks in a screenhouse were bud inoculated with a severe strain of tristeza virus. Thirteen months later, trees on ten varieties of the sour orange rootstock showed tristeza symptoms of premature flowering, stunting and chlorosis; those on Australian sour did not. Australian sour is apparently a sour orange hybrid. Trees on other rootstocks appeared normal. The largest trees were on Rangpur lime rootstock.

Exocortis virus in Florida. The existence of a new virus distinct from exocortis affecting *P. trifoliata* is postulated on the basis of examinations made in 1957 and 1958 on several hundred trees with the new histochemical test for exocortis (developed in 1957). The dwarfing of citrus on trifoliata rootstock in the absence of scaling is believed to be caused by this second virus. Experiments in Australia with the histochemical tests for exocortis confirm this finding. These results indicated that in addition to freedom from exocortis, techniques will have to be developed to detect the new virus when trifoliata is used as a rootstock. A specific test for the dwarfing virus has not yet been developed but measurements of trunk diameter above and below the union (in the Florida Budwood Program Index Plots) indicate that stunting is measurable on four-year-old budlings on Trifoliata rootstocks.

Seed transmission studies of xyloporosis virus in Florida. Approximately 2,000 seedlings from xyloporosis-infected parent trees (from seven varieties of citrus) and 70 hybrids from the breeding project have been topworked with healthy Orlando tangelo in order to test for transmission of the virus through seed. Three years after budding many of the trees are showing some signs of xyloporosis but the tests are still inconclusive. Numerous indications of transmission of xyloporosis through seed have been observed in orchards. Six infected trees were recently found among unbudded Orlando tangelos in the test plots of the Florida Budwood Registration Program.

The occurrence of wood pitting on unbudded citrus seedlings in California. Wood pitting was found on unbudded citrus seedlings grown as part of a breeding program at Brawley, California. During the past year, 72 additional unbudded seedling trees were examined, of which 28 had wood pitting of the type reported previously. Tests are now under way to determine the cause of this phenomenon.

Citrus variety improvement program for California and Arizona. Further progress has been made in furnishing virus-free budwood for the Coachella Valley of California and the Salt River Valley of Arizona. During the past year over 60,000 buds of 27 virus-free varieties of citrus were delivered to the Arizona nurserymen. This is a part of a long-term cooperative project with the Arizona Experiment Station on budwood improvement.

Budwood distribution program initiated in Texas. Virus-free budwood sources have been found by a virus indexing program which is continuing. The Rio Grande Valley Nurserymen's Association in cooperation with the USDA, the Texas Agricultural Experiment Station, and the Texas Department of Agriculture have propagated nine virus-free selections of old-line orange varieties for distribution to nurserymen. One virus-free nucellar red grapefruit included in this budwood distribution program is the only virus-free old-line red grapefruit known to exist..

Blight determination of effectiveness of systemic insecticides for killing leaf hoppers suspected as possible vectors. Xylem-feeding leaf hoppers of the sub family Tettiguelinae are suspected as vectors of blight. Cooperative experiments with Entomology and Plant Quarantine using blue sharp shooters, *Oncometopia undata* (Fab.) are in progress on potted Orlando tangelo seedlings to determine the lethal dose of Systox. After application of the Systox solution, pots were enclosed in heavy plastic bags to prevent the escape of toxic fumes. In preliminary experiments with Systox at the rate of one pint containing 1.175 ml. Systox, applies to one Orlando seedling in five quarts of soil, ten of ten hoppers were killed in 73 hours. Additional lots of hoppers were placed on the same plant at weekly intervals thereafter and were killed as follows: second lot of ten killed in 21 hours, third lot of ten killed in 12 hours, fourth lot of ten killed in six hours and fifth lot of ten killed in four and one-half hours.

Stubborn disease in California. It was found that acorn-shaped fruits somewhat characteristic of stubborn disease produced by a Koethen sweet orange tree contained no viable seeds when mature. On the other hand, normal mature fruits on the same tree had several plump, viable seeds. Studies are under way to determine whether a transmissible entity for seed abortion may be involved. Observations of 50-year-old Marsh grapefruit trees on trifoliate orange rootstock, some expressing exocortis and some apparently free of exocortis revealed no symptoms of stubborn thus indicating that exocortis virus is distinct from stubborn disease.

Phytophthora fungus in citrus in Florida. Basic studies are being made to determine (1) the species of phytophthora present and (2) distribution of the fungus causing root rot in citrus present in Florida. To date only *P. Parasitica* has been found. This species seems to be omnipresent. It has been maintained in culture at the Orlando laboratory for over a year without difficulty. Abundant zoospores have been produced and used in many inoculations of citrus hybrids and species, but results are incomplete.



Root and soil fungi in nurseries in Florida. With the objective of improving uniformity in nursery tree size, a survey was made of root fungi in the seedbed and in budded stock. This survey indicated that phytophthora may be a factor in the poor performance of young budded trees in the nursery. To test this possibility, four sizes of seedlings were lined out in soil plots treated with Nemagon, D-D, UPM, Captan, Phaltan, PCNB, and Shell 4741. The fungicides and nematocides are used singly and in combination but results to date are inconclusive.

Plans: Efforts will be made to find indicator plants for xyloporosis and exocortis that will shorten the test period now needed with the presently used indicator plants. The screening of citrus varieties in Florida for resistance to Phytophthora will be carried out.

We must learn more about the fungi which are involved in the root rotting which takes place either simultaneously with nematode entry or following along behind the nematode. In addition, it is not absolutely certain yet that these nematodes are not carrying a virus. Fungi, bacteria, and viruses involved in spreading decline, along with nematode, will be investigated. Another line of attack will be the investigation of the so-called predaceous fungi. This work is being continued.

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## NEMATODE CONTROL

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Problem: Recently accumulated evidence indicates that citrus is attacked and often seriously damaged by several different species of nematodes. More information is needed on the identity, life histories, distribution, interrelationships between the various nematodes and diseases attacking citrus, and effectiveness of biological methods and chemicals in their control or suppression.

Program: A continuing program of basic and applied research is being conducted at Orlando, Florida; Weslaco, Texas; and Tempe, Arizona, in cooperation with the Texas and Arizona Agricultural Experiment Stations and commercial growers. The program involves about four professional Federal man-years annually.

Progress: Nematocides in irrigation. Experiments in Arizona have shown that the citrus root nematode can be controlled by the application of about two gallons per acre of dibromochloropropane in irrigation water. Where this treatment was combined with "hedging," improved growth and yield were noted within a year.

Soil treatment. In greenhouse experiments in Florida, citrus seedlings growing in soil from spreading decline areas showed less damage where a fungicide (Captan) was mixed with the soil before planting. This indicates that the disease is probably a complex, involving fungi as well as the burrowing nematode.

Nematode screening. During the past ten months, 187 new chemicals obtained from the U. S. Department of Agriculture pesticide synthesis program, the EURDD, the SURDD, and from the chemical industry were evaluated for nematocidal activity. Two of these were sufficiently promising for testing on citrus seedlings growing in the greenhouse to warrant further evaluation.

Survival studies. Studies to determine the ability of the burrowing nematode and the root-lesion nematode to survive in fallow soil have been completed. The soil, taken from a naturally-occurring spreading-decline-infected grove, was maintained in the greenhouse. Soil was removed at monthly or bi-monthly intervals and planted to okra, a host capable of supporting heavy populations of both nematocides. Six weeks after planting, the okra roots were examined for nematodes. Under these conditions, the burrowing nematode survived fallow conditions for five months and the root-lesion nematodes have survived for 22 months. Three monthly readings subsequent to the 22-month period were negative for all nematodes.

Nematode migration. Greenhouse studies under more closely controlled conditions that can be maintained in the field are in progress to determine burrowing nematode mobility in the soil. The results indicate that under greenhouse conditions these nematodes can travel through soil or along roots

the maximum distance of 41.25 inches in seven months. The life cycles of these nematodes is approximately one month from fertilized egg to fertilized egg. Therefore, the members of an individual generation seem capable of moving a distance of approximately six inches.

Field fumigation. Field fumigation tests are carried out in established citrus groves infected with the burrowing nematode and the root lesion nematode using chemicals that are either commercially available or experimental ones that have been developed in the screening program.

This work, using effective nematocides such as D-D mixture, Nemagon and Dorlone or experimental materials that have demonstrated nematocidal activity in greenhouse tests, has been hindered by the fact that treated citrus does not show growth responses such as could be expected after nematode populations are lowered.

During the period covered by this report, three new field areas were sampled and mapped in preparation for field tests using combinations of nematocides and fungicides. Two of these areas have already been treated but results are not yet available.

Nematocides for ornamental nursery stock. Ornamental plants are hosts of the burrowing nematode and are known to be involved in the nematode's spread to citrus. This project, cooperative between the Nematology Section and Plant Pest Control Division, ARS, Winter Haven, was initiated to find a nonphytotoxic drench material that could be used to free commercially-grown ornamentals of the burrowing nematode. At the present time, infections are located and delineated by periodic sampling surveys and certification of ornamentals based on these results is essentially site certification. The best sampling methods are imperfect and it is thought that certification based on the use of a suitable nematocide rather than on negative sampling results would be a cheaper and more dependable arrangement.

So far, the work has been hindered by the inability of various experimental nematocides which move satisfactorily in light citrus grove soils, to penetrate through the heavy organic soils used in commercial ornamental plantings.

Assay of fungi in relation to migration. Growth responses of burrowing nematode-infected citrus seedlings growing in pots in the greenhouse after drench treatments with fungicides that did not control or otherwise lower burrowing nematode populations indicate the possibility that disease organisms other than nematodes can affect growth of spreading decline-infected seedlings. This work suggests that the burrowing nematode plus some other factors may be acting together to produce the symptoms on citrus of what has been considered a nematode affect only. The nematode migration studies described above offer an excellent opportunity to determine if there is a real change in the fungus populations with the presence and increase of nematodes. Results indicate that fungi of the genus *Fusarium* were most



commonly encountered and *Fusaria* were more frequently isolated from behind the margin of burrowing nematode infection than ahead of it. In addition, it was found that the *Fusaria* were isolated more frequently from the roots of the seedling grown in the original burrowing nematode-infested soil than from the seedlings grown in steam sterilized soil that later became infected with burrowing nematodes and various soil fungi. *Fusaria* were isolated from root sections taken from both sides of the margin for burrowing nematode infection and were recovered from the bark, cortical layers and woody cylinder of the roots.

Relation of various nematodes to citrus declines. The root-lesion nematode *Pratylenchus* spp. is present in over 95 percent of the citrus root samples collected in Florida. It is now thought that plantings free of this nematode do not exist. Records of this and other nematodes parasitic on citrus are being kept. Suspect nematode populations, when they are encountered, are used to inoculate the citrus seedlings so that their effect, if any, may be observed.

Plans: Work on practical chemical control in citrus groves will be expanded during the coming year.

The work on nematocides for treatment of nursery stock will emphasize formulation changes and methods of application as means of solving the problem.

Work will be continued on the other aspects of nematode control reported above.

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## E. Insect Control

## FRUIT FLIES AND THEIR CONTROL

ENT

Problem: The recent outbreak of the Mediterranean fruit fly which cost approximately ten million dollars to eradicate, points up the increasing danger of the accidental introduction of this and numerous other kinds of tropical fruit flies into the United States through the increasing number of ports of entries and volume of international travel. It is urgent that we develop up-to-date methods of control for each of the important fruit flies so as to have them available for immediate application.

Program: A continuing long-range program of basic and applied research dealing with the oriental fruit fly, melon fly, Mediterranean fruit fly and Mexican fruit fly carried on in Hawaii in cooperation with the Hawaii and California Agricultural Experiment Stations, Hawaii Board of Agriculture and Forestry, Pineapple Research Institute of Hawaii, Hawaii Sugar Planters Association Experiment Station, and in Mexico in cooperation with Mexican governmental agencies. The program involves about 18 man-years of Federal professional service annually.

Progress: Fruit Fly Lures. Work with possible new lures for the major species of fruit flies under study has been continued with the cooperation of the Pesticide Chemicals Research Branch in synthesizing or supplying candidate lures related to known attractants. Against the Mexican fruit fly, 1,371 new materials were tried, bringing the grand total to 4,366. In Hawaii, from 516 to 534 candidate lures have been screened against three species of flies in the last eight months, with field tests of all that showed adequate promise. No oriental fruit fly lures equal to the highly effective methyl eugenol have been found, but good progress has been made with lures for the Mediterranean fruit fly and the melon fly.

The present status of Medfly lures is that outstanding angelica seed oils superior to (but more costly than) the best synthetics, may still occasionally be found, that siglure (the synthetic lure used during the latter part of the Florida Medfly campaign), with its rapid volatilization rate has now been definitely surpassed by three longer-lasting synthetic lures, referred to as ENT-31560, 31322, and 30992. These are most promising, but in need of more extensive field investigation. Their low volatilization rates make them comparable to methyl eugenol and anisylacetone in duration of attraction and in greatly reduced amounts of lure needed to maintain traps, thus reducing both material and labor costs.

In Medfly field tests in coffee on the Kona coast of Hawaii, angelica seed oil, siglure, and ENT-30992 baited plastic traps caught more flies when exposed in sunny locations than in continuous dense shade. High temperatures and wind induce more rapid volatilization; hence the rates and frequency of application must be adjusted to the conditions under which the traps are to be used.

For the melon fly in Hawaii, anisylacetone has been the most effective available lure, but its effectiveness has been low. During the past eight months, several closely related compounds have been found more attractive. The most promising of these has been one referred to as ENT-31812. This material had been found by Australian workers to be attractive to the Queensland fruit fly. On wicks, small amounts of ENT-31812 were four to eight times as attractive as anisylacetone for up to two weeks. This lure, unlike anisylacetone, induces the flies to feed avidly, and it appears to be attractive to sexually immature males. Preliminary field tests indicate that it has all the value shown in the laboratory tests. In 12 days, initial applications of 0.2 gram captured from 473 to 1,037 flies (depending on method of use) compared to from 55 to 105 by anisylacetone. More extensive tests now under way have thus far fully confirmed these results.

In tests of toxicants for use with the methyl eugenol oriental fruit fly lure, Dibrom continued to give better results in traps than the former DDVP standard. On exposed cane fiber feeding stations the increase in kill amounted to 30 percent. Dimethoate and Velsicol 53-CS-17 were far inferior for this purpose.

Methyl eugenol plus DDVP exposed on cane fiber squares was as effective in attracting and killing oriental fruit flies when spread on the ground as when suspended in trees two feet to 25 feet above ground.

In survey work to detect incipient infestations of fruit flies, combination lures are most desirable. Because of the similar loss rates of methyl eugenol and ENT-30992, these and anisylacetone may be very useful in combination 3-lure traps for the three species of fruit flies found in Hawaii; however, in tests to date the ratios used depressed catches of the Medfly and oriental fruit fly as much as 65 and 50 percent, respectively. Melon fly catches were sometimes unaffected but generally were increased.

Results against the Mexican fruit fly have continued to be negative, in spite of the large numbers of possible lures screened. Only one material, the hexyl ester of palmitic acid, has consistently approximated the attractiveness of the fermenting standard in the laboratory. Unfortunately, it was not attractive in the field either when exposed alone or in combination with proven lures.

In the absence of an outstanding synthetic lure, studies of protein and sugar-yeast materials have been continued in Mexico. Staley's protein insecticide bait No. 7 was proved approximately five times as effective as the sugar-yeast lure over a period of a year with large fly populations in mangoes at 4,300-4,800 feet in Morelos. However, these results were reversed under conditions of light infestation in northeastern Mexico at Santa Engracia (el. 800 ft.) and at Linares (1,200 ft.).

Some decomposition and discoloration of the protein lures has occurred in some of the Mexico studies. Work is under way in cooperation with the California Department of Agriculture, to overcome this difficulty, but conclusive results have not yet been obtained.

Bait sprays. Twenty-one insecticide compounds have been screened in the laboratory with the Mexican fruit fly since the last report, making a total of 76 tested since the screening program began. Twenty-three of these have shown higher toxicity than technical malathion. These will be given further study.

In Hawaii, dimethoate proved to be more toxic to the oriental fruit fly and the melon fly than any compound tested heretofore. Bayer 29493 gave outstanding performance, being as effective in the fourth week as DDT was in the third and malathion and dimethoate in the first.

In two field experiments on guava, sprayed three or four times at biweekly intervals, Bayer 29493 gave outstanding results in oriental fruit fly control. Ethion and Trithion, similarly used, also performed much better than the standard malathion bait spray. All had been found far less injurious to automobile finishes than malathion. Delnav was least effective and showed no control in the second week. In tests against the Medfly on scattered, dooryard peach trees, Bayer 29493 also gave remarkable control. This compound apparently was responsible for some fruit injury after the first or second spray but no further injury developed despite heavy deposits. Because of the pubescence, small size of fruit, and their foliage, residues were high.

In other tests the microorganism *B. thuringiensis*, which has shown great promise against certain other insects, failed to produce any mortality of fruit fly larvae or adults, even when overdoses were incorporated in their rearing media or food.

Silica gels were found capable of producing substantial adult mortalities at excessive application rates -- 100 pounds per acre -- but the effect was of short duration and against the melon fly it was negligible.

In Mexico, 61 proteinaceous materials were tested as possible attractants for use in bait sprays. None of the 149 tried since the program was initiated was proved consistently superior to Staley's protein insecticide bait No. 7. In Hawaii, two feather and hoof meal hydrolysates when applied with malathion in four small-scale tests attracted and killed from 67 to 80 percent more fruit flies of all species than the standard SIB #7-malathion formula.

Soil insecticides. Field cage tests with soil toxicants for Mexican fruit fly are now in the fourth year. The best compound in one series was endrin emulsifiable at the rate of 7.6 pounds actual toxicant per acre with 79 percent mortality resulting in the mature larvae introduced more than three years after the soil was treated. Endrin wettable powder at six pounds was almost as effective, while heptachlor wettable powder at 12 pounds was the most effective with 69 percent mortality at nearly three years compared to 59 percent with endrin emulsion 7.6 pounds. Heptachlor emulsion nine-pound was ineffective.



Granular preparations are being intensively studied as soil toxicants as they are readily applied and with minor hazard. Although generally not as toxic initially as emulsions and wettable powders, mixtures are proving effective.

Fumigation of fruits because of fruit fly infestations. Further studies carried on by the Mexico City laboratory have resulted in the authorization of schedules of treatment that take into account temperature (60 or above) and load. Although dosage-mortality data at 50° F. were adequate to permit a recommendation for treatment at that temperature, there was indication of slight injury to grapefruit transported to the laboratory from northeastern Mexico. Further tolerance tests with ethylene dibromide on Ruby Red grapefruit in the Rio Grande Valley at fairly high dosages gave no injury and rot appeared to be normal. Recommendation for treatment at 50° F is under consideration. Over 11,000 tons of citrus was fumigated with ethylene dibromide in Texas during the past season.

Results of dosage-mortality tests with citrus in paper wrappers or packed in fiber mesh bags permitted recommendation for treatment at the same dosages as for unwrapped fruit.

Studies on the circulation and distribution of vaporized ethylene dibromide were made in a standard fumigation room in the Rio Grande Valley of Texas. Sorption readings showed that ventilating fans failed to distribute properly the ethylene dibromide during the evaporation period, whereas the forced draft type of circulation distributed it uniformly, and sorption was greater with forced draft.

Ethylene chlorobromide is being studied intensively as a fumigant as citrus shows much greater tolerance to it than to ethylene dibromide. There seems to be a possibility of treatment for the Mexican fruit fly with one dosage of ethylene chlorobromide for all types of pack and for all load levels.

In Hawaii, thirty-seven new materials were tested to determine fumigant action against fruit fly eggs and larvae, bringing the total tested to date to 375. Eight of these newer materials were found highly toxic to either the egg or larval stage. Five were tested against fruit fly infestation in papaya. None gave complete kill at a dosage of one or two pounds per 1,000 cu. ft. for two hours. Tolerance tests showed that only one compound, 2-bromo-ethyl ethyl ether, was tolerated by papayas at the 2-pound dosage.

Dips for papayas. Satisfactory schedules have been determined in Hawaii for one-shot, 20-minute papaya dips at temperatures of 110 and 115° F. Tests are now being conducted to determine a satisfactory method for continuous operation. One may be the use of an infusion pump which will add EDB to the dip solution at a rate balancing loss through evaporation. An alternate method, which indicates more promise for immediate use, is to start the dip at an initial concentration double that required to effectively control fruit flies and continue dipping until the concentration of ethylene dibromide has dropped to the minimum control level.

Gamma irradiation for commodity treatment. Mortality curves have been completed in Hawaii for naked eggs, larvae, and pupae of the oriental fruit fly, melon fly, and Mediterranean fruit fly, for larvae in rearing medium, and for egg and larval infestations in papayas and avocados. Although immediate kill is not obtained, development from the egg or larva to the adult stage is prevented by treatments of 10,000 r (roentgens) against the melon fly, 6000 r for the oriental fruit fly, and 5000 r for the Mediterranean fruit fly.

Chemical sterilants for the Mexican fruit fly. Twelve coded compounds supplied by Pesticide Chemicals Research Branch were tested as sterilants for the Mexican fruit fly. Although they did not kill the flies directly, they might cause the eggs laid by them to be sterile. Each material was added to the standard diet of 25 pairs of one-day old flies. Two of these compounds, added to the regular diet of the flies, reduced to low percentages the hatch of the eggs laid by the flies. Rearings of larvae from flies fed the other compounds are being made to determine if there are latent effects. The compounds will also be used in the carrot-yeast rearing medium to determine if they have any effect on immature stages.

Fruit fly population trends, distribution, and host plants. During the reporting period the oriental fruit fly populations in Hawaii have been at seasonal lows, but at favorable sites there have been considerable numbers of flies at all times. Mediterranean fruit fly populations declined to record lows in February on Hawaii and in April on Maui, largely because of short crops of loquats and early peaches. Melon fly populations reached their lowest levels in January 1959 on Maui and Hawaii, and have steadily increased since.

On Maui periodic guava sampling at permanent locations indicated that the percent fruit infested dropped from 43 in November to 13 in February, but had increased again to 45 percent by April. On Hawaii the infestation declined from 34 percent in November to 25 percent in February, but had increased to 50 percent by April. April infestations (last complete data available) average approximately the same as in 1958.

New records for the oriental fruit fly and Medfly were made by the finding of both of these species in the fruit known as Momordica. The oriental fruit fly was also reared for the first time from the fruit known as Wampi.

A survey for the Mexican fruit fly was conducted in the southeastern Mexico States of Tabasco, Campeche, Yucatan, and Quintana Roo in May and June. This area has become of interest because of a projected new tourist route through it. No Mexican fruit flies were trapped there, and no larvae of this species found in fruits, but many fruit flies of two closely related species were found. The northwest coast of Mexico was also surveyed late in June from Guaymas in Sonora to San Blas in Nayarit, a distance of 670 miles. Traps placed in six locations and fruit inspection failed to disclose the Mexican fruit fly at any location. The Mexican fruit fly is known to occur in that area, but apparently it reaches a very low point when seasonal conditions become unfavorable.



Fruit fly flight habits. Further studies of fruit fly movement have confirmed earlier indications that certain species, at least, move many miles, either by their own flight or by wind carriage. Large numbers of flies were released near the north tip of the island of Maui in a fruiting guava area. Eight oriental fruit fly males and one Medfly male were recovered directly downwind of prevailing trades on the island of Lanai after minimum flights of 20 to 25 miles with 8 miles overland before 12 miles over water. In more limited experiments the maximum flight recorded for the melon fly was 5 miles.

Fruit fly parasitization. In collections that were predominantly Medfly, total parasitization was less than 12 percent by four kinds of parasites on Hawaii, and 24.5 percent on Maui. Parasitization averaged 49 percent in guava on Maui and 30 percent in guava on Hawaii. It amounted to 78 and 73 percent in coffee and peach, respectively, on Hawaii and 44 and 22 percent, respectively, on Maui. In Jerusalem cherry at 4,700' altitude it was 7 percent. In fruits where the oriental fruit fly was the dominant species, parasitization ranged from zero in some fruits to 75 percent in Ceylon gooseberry.

Several shipments of parasites were made from Hawaii to the International Cooperation Administration in Costa Rica in support of their effort to colonize species that would assist in suppressing Medfly infestations there.

Preparations for large-scale eradication experiments. Certain isolated small islands in the western Pacific have been tentatively selected for the large-scale testing of newer eradication techniques, and final arrangements are being made with the Navy and Trust Territory officials involved.

One method, referred to as the sterile male technique, is the liberation of large numbers of flies that have been sterilized by exposure to gamma radiation. Male flies that have been so treated mate normally, but no fertile eggs are produced. Laboratory experiments in Hawaii and Mexico have indicated that this method should also be feasible with fruit flies.

Studies are under way in an effort to improve methods of producing and handling flies in connection with the proposed eradication experiments. Tests in Hawaii with a new microorganism inhibitor and with larger rearing trays are under way in an attempt to increase rearing efficiency, but conclusive results are not yet available. In a comparison of constant temperatures at 65, 70, 75, 80, and 85° F., the 80° level gave best results for all species from the larval period through emergence. At this temperature the larval periods were 5 to 6 days.

Studies have also been carried on to determine the most practical way of distributing the irradiated insects. For the most part it will be necessary to drop them from planes. Present indications are that dropping naked pupae results in excessive loss by direct injury or attack by ants. It may be necessary to drop them in containers that will protect them from various hazards, or to make the releases after the insects have become adult flies.



In Mexico, preliminary tests of the effect of irradiation on the Mexican fruit fly have been continued through the cooperation of the Mexican National Nuclear Energy Commission.

Plans: By readjustment of programs elsewhere, it is hoped to make a start on large-scale experiments on certain islands in the western Pacific with the eradication of fruit flies by the mass release of males that have been sterilized by irradiation. If possible the work will also include tests on other islands, of control of the oriental fruit fly by poisoning the male flies with a combination of methyl eugenol and a quick-acting insecticide. This readjustment may involve temporary partial curtailment of other phases of the fruit fly work in Hawaii.

A continuation of the work on the Mexican fruit fly is planned at about its current level, with special emphasis on the development of an effective lure for use in survey traps and more effective bait sprays for direct control, and more attention to biological control.

Publications: Effect of Variable Temperature Environments on Egg Development of Three Species of Fruit Flies. P. S. Messenger and N. E. Flitters. Annals Ent. Soc. Am. 52: 191-204, March 1959.

#### OTHER INSECTS AFFECTING CITRUS AND SUBTROPICAL FRUITS

ENT

Problem: More effective and economical insecticides and other measures are needed for better control of the many insects and mites (other than fruit flies) attacking citrus and subtropical fruits in the U. S. There is an urgent need for insecticides to which insects will not become resistant, that will not leave objectionable residues at harvest, and that can be integrated with biological methods of control which need further development.

Program: A continuing program of basic and applied research carried on at stations at Whittier, California, and Orlando and Lake Alfred, Florida, in cooperation with the respective State Agricultural Experiment Stations, involving about 6 professional man-years annually.

Progress: Citrus Red Mite Disease. The disease of red mites mentioned in last year's report as having been found in California, appears to be caused by a virus. Diseased mites studied with an electron microscope by Dr. Kenneth Smith at Cambridge, England, showed evidence of the presence of a virus. This is the first virus disease found in spider mites and opens a new field of possible value in control of an important group of pests. The disease is highly infective under laboratory conditions. Mortality generally begins within 10 days after inoculation and becomes complete or nearly complete in 15 days. Suspensions of diseased mites ground up in water retain infectivity for at least 56 days at 0° F. but are less stable at room temperature. One part of diseased material in 5,000,000 parts of water is infective in the laboratory. Methods of producing diseased mites have been improved in order to provide material for field experiments on citrus and to supply other workers with material for tests on different species of mites.

Practical value of the disease in the field is uncertain as yet. It has been found occurring naturally in scattered groves in southern California and in some of these the mite infestation became heavy enough to require treatment. In a field experiment, the disease was established by sprays of the disease suspension, and some reduction in rate of mite increase was indicated. However, the effect was not enough to prevent damage during a period of rapid mite increase in the grove. An unfavorable factor is the rapid loss of infectivity of the dried residues of the sprays. Studies of ways to improve effectiveness are under way.

Biological control in Florida. In the last year of a 5-year study of infestation levels of citrus insects and mites in two no-spray groves near Weirsdale, Florida, the populations of purple scales, Florida red scales, citrus red mites, Texas citrus mites, and rust mites have again remained low. The citrus and cloudy-winged whiteflies have again peaked up in early summer, but the beneficial fungi have reduced these infestations sharply. Since the severe freezes of 1957-58 sooty mold from the whiteflies has been abundant, because the Manatee snails have come back slowly and are too few to clean up the trees as they did before the freeze. The disease melanose has become prevalent in both sprayed and unsprayed orchards because of the winter-killed wood left by the 1957-58 freezes. Grapefruit trees were affected to the extent that the owner of one of the no-spray orchards applied basic copper sulfate sprays.

Surveys of Florida citrus groves have been continued, both from the Orlando and Lake Alfred laboratories. Several new finds of beneficial insects and mites have resulted, and much information on distribution, hosts, and value in control has accumulated. The State station at Lake Alfred and the Orlando laboratory are cooperating in collection of data on beneficial insects and mites, and the results will be published cooperatively as a preliminary annotated list.

The Chinese lady beetle, Leis, introduced into Florida many years ago has been found in its usual abundance this spring around Orlando, feeding on citrus aphids. It has not become established in other areas of the State. On the theory that the Leis have difficulty in sprayed groves in finding food in the long intervals between aphid outbreaks, colonizations will next be made in town areas where housing developments have overrun citrus groves and where there are many yard trees that are not sprayed. Several other kinds of lady beetles introduced several years ago have not been recovered.

The special Florida survey continues of the tiny wasp Aphytis, which attacks adult female purple scales and destroys 20 percent of them in unsprayed groves. It has been found working in sprayed groves also. No lessening of its abundance or control from it has been seen in 1959. If it continues at present levels, it will be a major factor in control of purple scales in no-spray groves in Florida. It may also be partially responsible for present prevailing low levels of purple scale activity in sprayed groves.



At Lake Alfred, Florida, a study is being made of the effects of insecticides and miticides on pests, parasites, and predators. Already large differences in pest infestation and associated differences in abundance of parasites and predators have been seen after use of some materials.

Insecticide studies. In California, two brands of special light oils with two emulsifiers used at the rate of 1 gallon of oil plus 0.25 pound malathion per 100 gallons, controlled black scale as well as 1-3/4 percent of light medium oil but were less effective on red mite. The light oils had less ill effect on exterior fruit quality and were followed by less water spot. However, a significant amount of water spot developed on Thompson navels, a very susceptible variety, sprayed with the light oils.

Dimethoate was more than 4 times as toxic as parathion to California red scales on the fruit in laboratory tests. Laboratory and field studies suggest that this material may be useful when combined with parathion to give good kill of scales on both fruit and wood. Silica gels were not effective.

Early postbloom sprays of parathion and malathion in one Valencia and one navel grove in central California caused no significant reduction in crop.

In Florida, a new experiment has been started in a Valencia grove near Orlando. The new grove has infestations of citrus red mites, citrus rust mites, and Texas citrus mites. The last was not present in previous locations. Two new materials, Ethion and Methyl Trithion, are being compared with oil emulsion, Chlorobenzilate, or Kelthane for control of red and Texas mites. On other Valencia trees we are trying to find out more about the causes of a marked build-up of red mites experienced last year after use of postbloom combination spray. Trees have been sprayed with malathion, parathion, wettable sulfur, and basic copper sulfate, used separately, to see which material tends to cause increase in infestation.

Delnav (Hercules AC-528), Chlorobenzilate, Ethion, Methyl Trithion, and Kelthane are being studied in Florida to find out if they exert any control effect on citrus rust mites.

Insecticide resistance. In 1958 large increases of citrus red mites occurred in a Florida Temple orange block sprayed with a basic copper sulfate, nutritional materials containing zinc and manganese, malathion, wettable sulfur, and ovex. A summer spray of malathion, wettable sulfur and ovex did not check these increases. June 1959 experiments involved use of most of these materials by themselves, to determine which were responsible for build-up or lack of control. Results will be determined later later in the year. Experiments have been set up on Valencia orange trees to see if resistance will follow repeated grove use of oil emulsion, Kelthane, or Tedion now for control of citrus red mites.

In California, citrus red mites resistant to demeton have lost about 60 percent of their resistance in 40 generations without further treatment. Another strain has lost about 50 percent of its resistance to ovex in 17



generations. The results support a practice of alternating materials with different modes of action in order to retard the development of resistance. Mites resistant to demeton and ovex were not resistant to Kelthane or Tedion, the best of our new materials for red mite.

Plans: Continue the program at about its current level. Continue the biological control studies now under way. Emphasis will be placed on studies of the virus disease of the citrus red mite that has been found in California, including studies on viability of the virus, methods of preparation and storage, effects of dilution, prolonging infectivity of dried residue and other subjects which are essential to understanding field behavior and conducting field experiments; produce disease inoculum for tests by other workers on various species of mites; conduct field experiments to study methods of starting infection in the field and the subsequent course of infection.

In the insecticide studies, emphasis in California in field studies on red scale will be on dimethoate. Initiate studies on effects of anti-metabolites and chemical sterilants on citrus red mite. In Florida, continue the studies of the value of newer scalicides and miticides, alone and in combinations, for control of red mites, Texas mites, rust mites, purple scales, Florida red scales, citrus snow scale, and whiteflies. Samples of fruit will be referred to cooperating chemists for residue analyses, where questions still exist.

Study seasonal history and biology of the citrus snow scale in Florida, in hope of finding times when insects are more susceptible to control with our best scalicides.

Continue investigations of insecticide resistance at least at its present level. In Florida, studies of possible resistance to Kelthane and Tedion will include the effect of alternating these and other acaricides upon retarding or preventing resistance. Studies on the resistance of the citrus red mite to various miticides will also be continued.

Publications: . Four Years of Experiments with New Miticides and Insecticides. Herbert Spencer and Allen G. Selhime. Proc. Fla. State Hort. Soc. 71:179-81. 1959.

A Purple Scale Parasite New to Florida Citrus. By Martin H. Muma and D. W. Clancy. Citrus Magazine 21(8):18, April 1959.

Effectiveness of Different Formulations of Insecticides Against California Red Scale. A. W. Cressman. Jour. Econ. Ent. 51(6):911-12. Dec. 1958.

A Disease of Citrus Red Mites. F. Munger, J. E. Gilmore, and W. S. Davis. Calif. Citrograph 44(6):190, 216. April 1959.

Effect of Timing of Parathion and Malathion Sprays on Orange Production. A. W. Cressman. ARS 33-53. May 1959. 4pp.

Experiments with Kelthane for the Control of Citrus Red Mites. Herbert Spencer and Allen G. Selhime. Citrus Magazine, pp.22-23, April 1959.

## INSECT VECTORS OF CITRUS DISEASES

ENT

Problem: More information is needed on the relation of insects to the spread of numerous virus and other diseases of citrus such as tristeza, exocortis, and xyloporosis in order to develop methods of controlling the insects, thereby reducing the rate of spread of the disease.

Program: A continuing long-term program of basic and applied research carried on at Orlando, Florida, by cooperating entomologists and plant pathologists in cooperation with the Florida Agricultural Experiment Station. The entomological work involves about one man-year Federal professional service annually.

Progress: During 1959 additional transmissions of the T<sub>3</sub> strain of Tristeza were made with the melon aphid, the spirea aphid (also known as the green citrus aphid), and the black citrus aphid. Symptoms similar to tristeza also appeared in Key lime test plants fed on by viruliferous green peach aphids. Tissue transfers were made to healthy Key lime test plants, but symptoms have not yet appeared in these test plants, and those in the original test plants disappeared under warm-weather conditions.

In studying possible vectors of xyloporosis virus, transmission tests were made with spirea aphids on Orlando tangelo test plants. Sources of inoculum were young sweet orange trees known to be infected with the xyloporosis virus. Xyloporosis symptoms take from two to eight years to appear.

Demeton (systox) used as a soil drench at the rate of two pints per 100 gallons of water on Orlando tangelo seedlings, killed blue sharpshooter leafhoppers (known to transmit citrus blight) which fed on the treated plants, as much as six weeks after the single treatment.

Vector studies of exocortis virus continued. Trifoliata seedlings were used as test plants, and inoculated sweet orange on trifoliata plants as sources of inoculum. Melon aphids were tested as possible vectors. It will be several years before symptoms appear if the aphids succeeded in transmitting the virus.

Plans: The studies of the insect vectors of the citrus viruses will be continued at its current level. Increased emphasis will be placed on ecological aspects. A survey of aphids has been set up in two citrus groves to study winged aphid migrations. Information on over-wintering habits, host plants, and other factors that would aid control methods is needed. The vector work with citrus blight, xyloporosis, and exocortis will include more insect species.

Publications: Transmission of T<sub>3</sub> Severe Strain of Tristeza Virus of Citrus by the Melon Aphid. Paul A. Norman and Theodore J. Grant. Jour. Econ. Ent. 52 (4): 632-634, August 1959.



## II. UTILIZATION RESEARCH

## A. Chemical Composition and Physical Properties

## COMPOSITION AND PHYSICAL CHARACTERISTICS

SU, WU

Problem: Deterioration of the color and flavor of processed citrus and sub-tropical fruit is seriously limiting expansion of this processing industry. Knowledge of the chemical composition and physical properties of these products is required for the development of improved processing procedures that will result in more attractive and stable products.

Program: A continuing long-term program of basic studies conducted in the laboratories at Winter Haven, Florida; Weslaco, Texas; and Pasadena and Albany, California, in cooperation with the industry, the experiment stations of Florida and California, and the California Institute of Technology, and involving between 11 and 12 professional Federal man-years annually.

Progress: Carbonyls in lemon oil. Studies at the Pasadena laboratory, on the isolation and identification of the aldehydes in lemon oil, revealed the presence of seven new compounds to bring the number of known aldehydes to 13. These aldehydes, particularly citral, contribute most of the characteristic lemon flavor and aroma and may be involved in off-flavors that occur during processing. Differences in the relative amounts of the major aldehydes appeared to be correlated with the geographical locations from which the fruit was obtained. The extremes were found in oils from fruit grown in the humid coastal areas and in the dry desert areas.

A method for recovering the flavoring aldehydes and ketones in pure form from lemon oil has been developed. The aroma of this mixture resembles that of a high grade sesquiterpeneless oil. This concentrated flavoring material should lend itself to special uses in food products. The method of recovery appears to have commercial application. Research on the effects of processing variables on the composition of lemon oil is reported in a later section of this report.

Coumarins in lemon oil. A new coumarin compound has been added to the list of eight compounds previously identified at the Pasadena laboratory. These new and interesting compounds are being studied to determine their possible pharmaceutical usefulness. Derivatives of these compounds are known to have skin photosensitizing properties.

Flavonoids in citrus products. Methods have been developed for isolating and purifying eriodictin from lemon preparations, and determining its chemical and physical properties and structure at the Pasadena laboratory. These results are of importance because (1) next to the well-known hesperidin, eriodictin is the most abundant flavonoid present in lemons, (2) it has been demonstrated by the Pharmacology Laboratory that eriodictyol (the aglycone of eriodictin) has definite physiological activity in test animals. A patent has been issued on the preparation of eriodictyol from lemons.

Further progress has been made on the correlation of chemical structure with the bitterness of flavonoid glycosides. Previously it has been shown that naringin, the bitter flavonoid in grapefruit, contains the disaccharide



neohesperidose as its sugar component. Evidence now has been obtained that flavanones which are linked to this disaccharide are intensely bitter, and it appears there are at least three of these bitter glycosides in citrus fruits. One of these compounds (neohesperidin) is largely responsible for the bitterness of the Seville orange. A knowledge of the chemical structures of the bitter substances in citrus fruits will make it possible to develop methods for preventing or minimizing bitterness in citrus products.

Additional flavonoids have been isolated from lemons during the past year and several have been purified and submitted for pharmacological testing.

Polyphenols in dates. The darkening of dates has been found to be caused by two separate chemical mechanisms, one oxidative and the other nonoxidative, by work at the Pasadena laboratory. It was observed that darkening was reduced by 50 percent when dates were held in the absence of oxygen, i.e., under vacuum or inert gas. The polyphenolic constituents (tannins) in dates are being investigated to determine their role in causing darkening. A wide array of these complex compounds has been shown to be present in this fruit. The major constituents, which are complex leucoanthocyanidins, have been separated and partially characterized. Chemical changes associated with deterioration of dates such as inversion of sucrose, increased acidity, absorption of oxygen and production of carbon dioxide have been studied. The increased understanding of the mechanisms causing darkening and deterioration of dates resulting from these studies is proving useful in the development of new and improved methods of processing.

Carotenoids in Oranges and other fruits. The research on carotenoid pigments in oranges and other fruits has been continued at the Albany, California, laboratory to obtain more information on the specific compounds present, with the aim of determining how they participate in development of off-flavor in orange juice powder and other dehydrated fruits.

Off-flavor development was studied on canned samples of filtered orange juice and synthetic mixtures to which carotenoid fractions had been added. It appears that the carotenoids play a small part in the flavor changes, since it has been found that the changes are less pronounced when carotenoids are absent from either basic preparation. Further studies on low moisture systems are indicated, to see whether these will produce differences in the relation of carotenoids to off-flavor.

Other work has been carried on in further determining chemical characteristics of carotenoids found in the fruit products. The accepted method for detecting and differentiating types of carotenoid epoxides has given questionable results. An improved procedure has been developed for locating these oxygen bridges which have figured so prominently in the changes in carotenoids in aging of various processed fruits.

Carotenoid pigments of grapefruit. Continued work at the Weslaco laboratory has shown that the white varieties of grapefruit contain the same series of carotenoid pigments as are found in the colored varieties

but in much lower concentration. This observation indicates the possibility that mutation to colored varieties might have resulted in an increased amount of pigment precursors being supplied to the fruit from the rest of the plant. An experiment involving the grafting of small fruit of one variety onto a tree producing fruit of another variety indicated that the color of the fruit was not changed by the reciprocal grafting.

In continued cooperative work with the California Institute of Technology, the biochemical pathways of pigment formation are being studied with the aid of radioactively labeled substrates. An intermediate between mevalonic acid and the carotenoids, has been tentatively identified. Further data have been obtained indicating the presence (at least in tomatoes, which contain the same predominant red pigment, lycopene, as red grapefruit) of several compounds which appear to be isoprenoids but do not have the properties of sterols or the known carotenoids. The role of these compounds in carotenoid synthesis is still being investigated.

Bitter constituents of orange peel. Previous work at the Winter Haven, Florida, laboratory has indicated that flavonoid substances are only partly responsible for the bitterness in Florida orange peel and that additional bitter substances are volatile in steam and can be recovered from a distillate. Two of these volatile substances have been identified as linalool and alpha-terpineol. A method for their estimation in peel oil has been developed and some progress has been made on their estimation in peel juices and in commercial orange juices. Taste panel evaluations have shown that at least 25 percent of the bitterness of peel juice is due to flavonoid substances and about 30-35 percent is due to linalool and alpha-terpineol.

Oxidized flavors in citrus products. By using several different isolation techniques, six, and possibly seven, substances have been isolated from oxidized flavored orange juice. One of these appeared to be d-limonene. Efforts were also directed toward methods of inducing the formation of off-flavors in both orange and grapefruit concentrates, by whipping air into them and then returning the concentrates to 0° F. storage. Two orange and one grapefruit concentrate have developed definite, though not yet strong off-flavors after one to three month's storage. It is hoped that with further storage the characteristics which it is desired to isolate and study will become more pronounced. (Winter Haven, Florida)

Soluble solids in juices and concentrates. In continued work at the Winter Haven, Florida laboratory, effort is being made to establish empirical relationships between soluble solids of citrus juices and concentrates as determined by vacuum drying and by the refractometer; also, between the former and soluble solids as determined by the hydrometer or pycnometer. Determinations of soluble solids and total solids by the various methods, and insoluble solids where applicable, have been completed on 24 samples of single strength orange juice, 16 samples of single strength grapefruit juice, 15 samples of concentrated orange juice, and 12 samples of concentrated grapefruit juice. Samples were selected to



cover a wide variation in composition. Ratios between soluble solids by drying and Brix values by the refractometer, and between soluble solids by drying and Brix values from specific gravities have been calculated for each sample. Averages have been drawn for each relationship for each type of product, but the data have not yet been subjected to statistical analysis.

Organic acids in grapefruit juice. Evidence of the presence of at least six acids was found at the Winter Haven, Florida, laboratory. None was identified; the melting points do not agree with published values for the known acids of grapefruit.

Plans: Work will be continued at the present level to establish the identity of the remaining constituents in dates and citrus oils, juices, and concentrates, except the work on organic acids in grapefruit juices which will be held in abeyance for this next year. Special effort will be directed toward early publication and distribution to the industry of the results of the estimation of soluble solids.

Publications: A Review of the Chemistry of Citrus Flavors. W. L. Stanley. Presented at A.D. Little Company Flavor Symposium, Chicago, Oct. 1957. Published as a chapter in "Flavor Research and Food Acceptance," Reinhold Publishing Corp., N. Y. 1958.

Occurrence of Coumarin Analogs in Lemon Juice. R. A. Bernhard. Nature, 182 1171. 1958.

Specific Quantitative Colorimetric Method of Analysis for Citral in Lemon Oil. W. L. Stanley, R. C. Lindwall, S. H. Vannier, Agr. and Food Chem., 6 (11), 858. 1958.

Date Research Program at the Pasadena Laboratory. V. P. Maier and F. H. Schiller. Date Growers Inst. Report 35, 13-15. 1958.

Process for Production of Eriodictyol. Robert M. Horowitz. U. S. Patent No. 2,857,318, issued Oct. 21, 1958.

Pigmentation, Pigment Analysis and Processing of Colored Grapefruit. B. J. Lime, T. S. Stephens, A. E. Purcell, and F. P. Griffiths. J. Rio Grande Valley Hort. Soc. 13: 30-38, 1959.

Carotenoid Pigment Formation in Colored Grapefruit. A. E. Purcell. J. Rio Grande Valley Hort. Soc. 13: 39-44. 1959.

Seasonal Development of Carotenoids in Grapefruit. A. E. Purcell. J. Rio Grande Valley Hort. Soc. 13: 45-53. 1959.

The Incorporation of Mevalonic Acid into Tomato Carotenoids. A. E. Purcell, G. A. Thompson, Jr., and James Bonner. J. Biol. Chem. 234(5): 1081-84. 1959.



## B. New and Improved Food Products and Processing Technology

## IMPROVED GRAPEFRUIT PRODUCTS

SU

Problem: The amount of bitterness in processed grapefruit products is the greatest obstacle to increased consumer acceptance and its removal or reduction should lead to expanded markets. Consumer appeal of products of pink and red grapefruit would be improved by better preservation of the color.

Program: A continuing program involving fundamental and applied research in the laboratory, pilot-plant, and in processing plants in cooperation with the industry and the State Experiment Stations of Texas and Florida, in USDA laboratories at Winter Haven, Florida, and Weslaco, Texas, and involving about four Federal professional man-years annually.

Progress: Bitterness of grapefruit juice products. In continued work at the Winter Haven, Florida, laboratory, techniques have been developed which have separated eight of the approximately 15 minor constituents demonstrable on paper chromatograms of filtered grapefruit juice. All of these are contaminated with small amounts of other materials, but some indication of their chemical nature could be obtained from ultraviolet absorption curves. No bitter-tasting fractions were obtained which were free of naringin, and it is believed naringin is the sole important bitter component. One of the two detectable substances which interfere with the Davis test for naringin has been obtained free of naringin, but is contaminated with large amounts of another substance from which it has not been separated by any technique yet tried. None of the components other than naringin has yet been identified.

At the Weslaco, Texas, laboratory, efforts to correlate Davis test values with actual bitterness (taste) of enzyme-treated products demonstrated that the Davis test was completely unreliable when applied to partially debittered grapefruit products and that discrepancies exist in the values obtained on analysis of normal juice obtained from fruits of differing maturities. Separation of naringin of grapefruit juice from the sugars and fruit acids and from a nonbitter material which gives a false positive Davis value has been accomplished. Spectrographic curves confirm the identity of the naringin but the other material has not been identified. In juice from fruit of normal maturity it appears responsible for approximately 10 percent of the usual Davis value.

Reduction in bitterness in grapefruit products. Work was completed at the Weslaco, Texas, laboratory on development of a method for reducing the bitterness of grapefruit juice, pulp, and other products through treatment with the enzyme naringinase, which splits the principal bitter component, naringin, into nonbitter compounds, without apparent undesirable effect on the quality of the products. The best conditions for commercial application of the debittering process were determined, namely, prior treatment (pasteurization) of the juice or pulp, minimum effective concentration of the enzyme, optimum temperature and time required for debittering effect of the enzyme on taste and on the Davis test for naringin, inactivation of the enzyme after debittering, and the effects of subsequent processing and storage of enzyme-treated grapefruit products.

The findings of this work were made available to industry by presentation at the 1958 meeting of the Institute of Food Technologists and subsequent publication. There has been considerable commercial interest in the possibilities of partially debittering grapefruit products by such a process.

Utilization of poorly colored grapefruit. As a final step in the processing phase of this investigation at Weslaco, Texas, white and red juice from late season fruit was fortified with highly-colored pulp saved from early season fruit and along with unfortified white and red juice controls, canned and placed in storage for consumer taste testing by the Agricultural Marketing Service. This consumer preference test will be made in a city where the public has not been subjected to a high level of advertising of either red or white grapefruit juice.

Last year canned juices were prepared for a similar test by the Department of Agricultural Economics of Texas Agricultural and Mechanical College. Triangle taste tests in both Houston and Dallas demonstrated a 61 percent preference for pulp-fortified red juice, 24 percent for Texas white juice and 15 percent preferred Florida white juice. Since the Texas pulp-fortified red juice and the Texas white juice were practically identical as to taste and chemical characteristics, the preference was due to differences in color, the public unconsciously picking the more highly colored juice as better. Since the publication of the results of the Texas test, more Texas canners have become interested in pulp fortification as a method of getting a superior colored canned juice.

Chilled grapefruit juice products. During the 1958-59 season, at Weslaco, Texas, early season, midseason, and late season packs of grapefruit juice, orange juice, and grapefruit-orange blends were prepared, processed, stored at 32°, 40°, and 50° F., and the keeping time and quality determined. The advantages of 32° F storage, both in keeping time and taste quality were repeatedly demonstrated. At this temperature grapefruit, orange, and grapefruit-orange blend juices can be stored for as long as 28 days after heat stabilization treatments of 165-180° F. Storage at 40° F. reduces the keeping time to 21 days or less, even though higher temperatures (170-180° F) are used for stabilization. When stored at 50° F., samples spoiled in 14 days. Even after heat treatment of 180° F., samples of all three juices consistently had a higher taste quality when stored at 32° F. than when stored at 40° F. Seasonal differences in the quality of the juice did not appear to greatly influence the length of time stabilized juice could be kept.

Plans: Continued effort during at least two more years will be directed toward isolation and identification of the substances which interfere with the Davis method for determination of naringin and the development of either a specific chemical method for the determination of the constituent or a method of correcting for the interfering substances. An attempt will be made to devise better chromatographic methods of separating bitter and nonbitter constituents of grapefruit which give positive reactions to the Davis test. Such procedures will facilitate more reliable application of the test as a means of following maturity changes and of evaluating the real (naringin) bitterness of grapefruit juice and other grapefruit products.



If continued basic research reveals other constituents that contribute significantly to the bitterness of grapefruit products, efforts will be made to devise treatments to reduce their effect.

Publications: Production of Canned Pulp-Fortified Red Grapefruit Juice. By J. B. Lime, T. S. Stephens, and F. P. Griffiths. ARS 72-12, 10 pp. 1958.

Debittering of Grapefruit Products with Naringinase. By F. P. Griffiths and B. J. Lime. Food Technol. August 1959, Vol 13, pp. 430-433.

## MICROBIOLOGY OF CITRUS PRODUCTS

SU

Problem: Spoilage due to microbial activity is a problem with all kinds of processed citrus products but it is particularly acute with chilled juice and sections or salad mixtures where the product is stored at above freezing temperatures. There is need for more information on the kinds and biochemical activities of microorganisms present in fresh fruit that develop during processing and in the distribution system.

Program: A continuing long-term program of basic and applied research on the microbiology of citrus products is carried on in SU's Winter Haven, Florida, laboratory, involving about one Federal professional man-year annually.

Progress: Storage experiments in the laboratory at Winter Haven, Florida, with several different lots of chilled citrus salads demonstrated the shelf life to be: two days at 70° F., with or without sodium benzoate as preservative; four to seven days at 60° F., with or without sodium benzoate; eight to 28 days with benzoate and eight to 14 days without benzoate, at 50° F.; and 37 to 42 days with benzoate, and 35 to 37 days without benzoate, at 40° F. In some cases benzoate had an appreciable effect on shelf life at the lower temperatures. Benzoate was determined in one series of commercial samples to be 0.044 percent in the cover sirup, of which only half is in the bacteriostatically-active, undissociated form at the observed pH of 4.2. Over a hundred million organisms per ml. were found in the cover sirup of some samples at the time of spoilage at 60° F. The total count decreased as the storage temperatures of other sub-lots of this series decreased. Cultures isolated from spoiled samples were tested for off-odor development in filtered orange and grapefruit juice blends. Most cultures that showed growth failed to produce characteristic off-odors; but some had aromas resembling vinegar, apples, diacetyl, ethyl acetate, yeast fermentations, and sauerkraut. The predominant organisms at 40° F. were yeasts and molds while 50° F. and above favored the more rapidly growing organisms, such as *Leuconostoc*.

Plans: The effectiveness of sodium benzoate, ascorbic acid, dehydroacetic acid and mixtures of these as preservatives of chilled citrus salad will be investigated. The effect of pH and temperature on the anti-microbial activity of these compounds, within the normal limits for this product, will be examined in detail.



# TIME-TEMPERATURE TOLERANCE OF FROZEN CITRUS AND SUBTROPICAL FRUIT PRODUCTS

SU

Problem: Much of the poor quality of frozen citrus products experienced by the householder is probably due to improper temperatures encountered between the time it leaves the processor and is opened for use in the home. More information is needed on the effect of exposure to selected time-temperature patterns within ranges likely to be experienced during distribution and marketing on the residual storage life under household conditions (40° F.).

Program: A continuing program of basic and applied research on the factors affecting the storage life of frozen orange concentrate is carried on in SU's Winter Haven, Florida, laboratory and in cooperation with citrus processors when commercial samples are used; involving about one Federal professional man-year annually.

Progress: Frozen orange concentrate. In continued tests at the Winter Haven, Florida, laboratory, the reduction in residual storage life was marked at 20° F. in two months, and relatively slight at 10° and 5° F. after six months. Again, there was wide variation between brands in respect to initial shelf life. The residual shelf life after adverse storage cannot be predicted from the initial shelf life since the proportion of the shelf life retained also varies widely between brands. Two lots had initial shelf life of 13 and 12 days, respectively. After storage at 20° F for two months and 0° F. for ten months, the residual shelf life was 0 and seven days, respectively. This appears to be related in part to the initial water-soluble pectin content. The effect of divided periods of storage at adverse temperatures was found to be equal to a single exposure of the same total duration.

Peculiar to this investigation of storage life is the observation in some concentrates of gelation without loss of cloud. In former studies, poor cloud was noted even though no gelation occurred, but gelation was always accompanied by loss of cloud. This is not understood, but may be related to processing techniques.

Samples gathered during the 1957-58 season, following extensive freeze damage, have been subjected to the time-temperature patterns. The determination of residual storage life is now in progress. The initial shelf life of commercial samples varied from seven to 44 days. Additional samples were collected during the 1958-59 season to observe the effects of the newly introduced pulp washing process.

A series of 42° Brix (4 fold), 53.5° Brix (5-1/3 fold), and 58° Brix (6 fold) concentrates were prepared in the pilot plant from a uniform lot of commercially obtained juice during the 1957-58 season. The taste panel was able to detect a flavor difference between portions held at 40° F. and 0° F. with the 4-fold at eight weeks, with the 5-1/3 fold at 14 weeks, and with the 6 fold at 12 weeks. Studies on cloud stability are still incomplete. During the 1958-59 season two additional series of 4-, 5-1/3-, and 6-fold concentrates were made in the pilot plant using commercial juice with pulp washing and these are also included in this study.

It was found that a water extract of grape leaves contained an inhibitor of pectinesterase and it was also found that this water extract would stabilize the suspended solids in reconstituted orange concentrate. It is believed that changes in cloud stability are related to changes in the pectin stabilizing the cloud. It was found in all samples investigated to date that water-soluble pectin decreases during adverse storage. The loss in water-soluble pectin is accompanied by an increase in Versene-soluble (low methoxyl) pectin.

Plans: The studies of time-temperature tolerance in terms of residual shelf-life will be continued in order to evaluate adequately the effect of many variables on product quality, including increasing the temperature of the evaporator feed juice (for the product from freeze-damaged oranges), and adding pulp washings to the juice going into concentrate -- variables which have been introduced in industry practice.

#### NEW PRODUCTS FROM SUBTROPICAL FRUITS

WU, SU

Problem: The growers and shippers of subtropical fruits such as dates, avocados, and limes grown at the present time principally for the fresh market, are urgently in need of a profitable outlet for the portion of their crops which do not meet fresh market grade standards. The development of new processed food products would help meet this need as well as providing diversification for the processors in the respective production areas.

Program: A continuing program of short-term and long-term problems of applied research carried out at the Pasadena and Weslaco laboratories in cooperation with the Date Administrative Committee of Indio, California, Rio Farms, Inc., Edcouch, Texas, the Texas Agricultural Experiment Station, industry members, and involving less than one Federal, and one industry-sponsored professional man-year annually.

Progress: New date products. Work at the Pasadena laboratory on new date products has resulted in the formulation of a highly acceptable chocolate-coated date bar. Several types of date fillings were used, including date-walnut, date-peanut, and date-almond mixtures. These bars have excellent stability at room temperatures. Samples have been submitted to interested date processors and candy manufacturers for commercial evaluation. Another date candy, a jelly confection, has been developed through cooperation with SU using a puff-dried date powder developed from these studies. This confection contains 25 percent date powder which imparts a good flavor and color.

The darkening of date puree has been retarded by adding small amounts of a combination of citric and ascorbic acids. Neither acid alone was as effective as the combination of the two. This treatment should be applicable to various date products.

Some progress has been made in preparing the date pieces for adding to breakfast cereals which will not become hard in texture during storage.



Improved frozen guacamole from Texas-grown avocados. In further work at the Weslaco laboratory on production of a frozen avocado mixture for guacamole, trials were made of "Ceredex No. 265" as a thickening agent to reduce or prevent watery separation of the product upon thawing for table use. Earlier experiments had demonstrated that a combination of waxy rice flour and sodium alginate was effective for this purpose, without affecting the flavor. Waxy rice flour is, however, difficult to obtain. In the present experiments, batches of guacamole were prepared from formulas in which Ceredex No. 265 was substituted for waxy rice flour. After freezing and holding for three days the products were thawed and compared with batches prepared from formulas in which waxy rice flour was used. None containing Ceredex exhibited any off-flavor, and a combination of this thickener and sodium alginate was just as effective as a combination using waxy rice flour in preventing excessive watery consistency. The product from a formula containing the Ceredex alone, without alginate, was somewhat more watery, after thawing, than guacamole containing waxy rice flour alone, but was considerably better than the product from a formula without any thickening agent.

Trials also were made of substitution of canned for fresh tomatoes in the frozen guacamole formula. The product was rated good by all judges. The canned tomatoes could be detected by all, but only one objected to the flavor. Should the formula be used in commercial operation, it would be possible to substitute canned tomatoes during months when the fresh fruit could not be obtained.

Plans: Future investigations on utilization of avocados will depend upon development and selection of new strains and varieties to be evaluated for processing. Utilization research on limes, Meyer lemons, and other minor fruits grown in the Southern region will be undertaken as there is a demand for new and improved products and processing technology, and as assistance is requested by industry and State and Federal research agencies.

Work will be continued at about the present level on the development of new date products and their uses in food products.

Publications: Evaluation of Some Physical Methods for Determining the Moisture Content of Dates. By F. H. Schiller and V. P. Maier. Date Growers Inst. Report 35, 19-22. 1958.

## PROCESSING PROCEDURES

WU

Problem: Information is lacking on processing procedures that will yield more stable fresh-fruit-flavored citrus products.

Program: A continuing long-term program of research on processing of citrus products is carried on at the Pasadena laboratory of WU involving one professional Federal man-year per year.



Progress: Debitting orange juice. Work has been started at the Pasadena laboratory on the development of an enzymatic method for debittering citrus products containing neohesperidin, which is closely related to naringin. Results are not yet available.

Processing variables on composition of lemon oil. Further experiments of the effects of processing variables on the composition of lemon oil at the Pasadena laboratory indicated that a 10-fold increase in the water-to-fruit ratio used during the expression of the oil had only a slight effect on the actual citral content. At the highest water-to-fruit ratio a noticeable loss of the lower molecular weight aldehydes was observed. This may account for previous reports that high water-to-fruit ratios resulted in lower citral content. Undoubtedly, these reports were based on analyses of the total carbonyl content of the oil calculated as citral rather than on the actual citral content. Such a method was developed during the course of these studies.

Plans: Work will be continued at the present level.

Publications: Effects of Environmental and Processing Factors on the Citral Content of Lemon Oil. By W. L. Stanley and S. H. Vannier. Food Technol., 8 (2), 96-99. 1959.

#### FACTORS AFFECTING PROCESSING CHARACTERISTICS

SU

Problem: The processing industry is in need of more precise information on the effect of many factors such as rootstocks and freeze damage on the quality of the raw product for processing purposes.

Program: A continuing long term program of applied research carried on at Weslaco, Texas, and Winter Haven, Florida, in cooperation with Crops Research of ARS and the industry and involving about one Federal professional man-year annually.

Progress: Freeze-damaged oranges. Increased finisher pressures resulted in increased juice yields, pectinesterase (P.E.) activity, total pectin, flavonoid content and relative viscosity values. Where flavor differences were indicated, juices of low pressure finishing were better than those of high pressure finishing. No differences were demonstrated in either physical characteristics or flavor of processed products of single lots of both Parson Brown and Pineapple varieties which had been separated into two sub-lots each, according to the extent of physical damage resulting from freezing. The time intervals between freezing and harvesting did not affect the P.E. activity, total pectin, soluble pectin, flavonoids, relative viscosity, cloud stability, or gelation. Juice yields decreased as the time interval between freezing and processing increased within each variety. Valencia products were of lower relative viscosity, P.E. activity, and total pectin values, and of better flavor than those of Parson Brown or Pineapple oranges. No new work along this line is contemplated unless another severe freeze occurs.

Rootstock on red grapefruit. The fourth and final year of cooperative work at Weslaco, Texas, has been completed and a publication is being prepared. Of seven varieties of rootstock tested, Sour Orange produced the highest quality red grapefruit in the 1958-59 season. Rough lemon produced slightly higher yields and the size and color of fruit were good; but the taste was rated lower than that of fruit from Sour Orange rootstocks. The data for the entire four-year investigation give a comprehensive picture of chemical and physical variations in fruit on seven different rootstocks at four different times during each season. The way in which commercially available rootstocks produce under conditions of virus and other citrus disease infestations is indicated. Although no variety of rootstock ranked better than Sour Orange, Rough Lemon and Red Blush were rated high enough in fruit production qualities to be considered as possible substitutes for Sour Orange if that variety should become vulnerable to virus or other diseases.

Plans: Work completed.

Publications: Processing Freeze-Damaged Oranges. By O. W. Bissett. Proc. Fla. State Hort. Soc. 71: 254-258. 1958.

### III. MARKETING RESEARCH

#### A. Market Potentials, Preferences, and Development

##### MARKET POTENTIALS AND CONSUMER PREFERENCE

MD

Problem: Increasing production of citrus and subtropical fruit products requires constant efforts to maintain and expand markets through new products and uses, and through other marketing innovations. To evaluate the potentials of innovations in marketing, information is needed concerning consumer preferences for new products and new product forms.

Program: The program is one of continuing marketing research involving field studies and analyses on a national, regional, or local basis, in cooperation with utilization research, state experiment stations, and agricultural producer, processor, and distributor groups and involving about one professional man-year annually.

Progress: An experiment was conducted with a panel of household consumers in Des Moines, Iowa, to determine the relative preferences of consumers for canned grapefruit juice processed from red and white varieties of grapefruit, both with and without the pulp added to the juice. The data are being analyzed to evaluate the potential market acceptability of red pulp-fortified juice. A report is planned for fiscal year 1960.

Research was conducted in Fort Wayne, Indiana, during the past year to determine the consumer and the retail trade's acceptance of an artificially sweetened canned grapefruit juice, offered in large (46-ounce) cans, promoted as a low-calorie grocery item rather than a dietetic food, and priced competitively with canned sugar-sweetened grapefruit juice.

Total sales of canned grapefruit juice increased over 50 percent after artificially sweetened grapefruit juice became available in the test market. Sales of canned sugar-sweetened grapefruit juice were unaffected by the availability of the test product. Sales of unsweetened grapefruit juice dropped somewhat, but this appears to have been the result of a combination of higher price, low shelf stocks and nonavailability. Consumers indicated a high degree of satisfaction with the product. A high proportion of users reported repeat purchases and indicated they would continue to purchase the product if it were available. Fieldwork on marketing artificially sweetened canned grapefruit juice has been completed. A final report is being prepared.

Plans: Studies in retail food stores and among consumers will be continued. Research will be initiated in the 1960 fiscal year to determine consumer reaction to "color added" vs. "natural color" in fresh oranges. Included will be retail measurement of sales under controlled conditions and household surveys to determine consumer opinions. Increased knowledge of consumer reaction to color in fresh citrus fruit will assist the industry in tailoring advertising, educational, and merchandising programs.



Research also will be initiated to determine specific quality characteristics in California oranges considered objectionable by wholesalers and retailers and consumer awareness of and attitudes toward such defects.

Publications: Marketing Artificially Sweetened Canned Grapefruit Juice. By Robert E. Frye. (Speech to Florida Citrus Commission and Florida Cannery Association, MD, AMS, May 13, 1959.)

#### IMPROVED MERCHANDISING

MD

Problem: A continuing need exists to encourage improvements in the retail merchandising of citrus and subtropical fruit items to maintain a strong competitive position for such products in the market place.

Program: The program is one of long-term marketing research conducted on a national, regional, and local level depending on the specific need. In most instances, research is conducted in retail food stores and involves close cooperation of store management. Less than one professional man-year annually is involved.

Progress: The findings of a controlled retail store experiment in Minneapolis, Minnesota, indicated that sales volume of smaller California and Florida oranges were significantly greater when displayed 100 percent prepackaged in polyethylene bags of one dozen per unit, or in a combination display of prepackaged plus bulk, than when displayed in bulk alone.

Larger California oranges, when tested six per package using polyethylene bags or paper trays, either sleevewrapped or overwrapped, and displayed in combination with bulk, resulted in equal sales regardless of package types. Sales were also about equal for 100 percent packaged displays using paper trays, sleevewrapped and overwrapped. Analysis has been completed.

Plans: Publication of results of the packaging and container study in Minneapolis will conclude this phase of the work.

A study of retail pricing of fresh lemons is planned in the 1960 fiscal year. This will include retail store tests, if feasible, to determine the effect on sales and returns of varying the retail price of fresh lemons from the customary markup. Producer groups believe that a comparatively high retail markup for fresh lemons is hampering efforts to expand sales and that prices reflecting lower markups would benefit retailers as well as producers. An evaluation of unit vs. pound pricing and of various types and sizes of containers for prepackaging of lemons may also be included. A manuscript, "Effectiveness of Selected Canned Food Displays in Supermarkets," is cleared for publication by Agricultural Marketing Service in the Marketing Research Report series.

## PURCHASE AND DISTRIBUTION PATTERNS

MD

Problem: The production of citrus during the past two seasons was below average, resulting in marked changes in price levels, reduced production of certain products, and shifts in consumer purchases of citrus and competing products. To maximize returns to growers, it is necessary to obtain continuing information on household purchases and retail availability of citrus and competing products as a means of increasing the efficiency of marketing efforts and of obtaining the best possible distribution of supplies of citrus products.

Program: The program on a long-term continuing basis is to obtain and publish periodic data on a national and regional basis on volume of household purchases of citrus and competing products, average prices paid, and the characteristics of buying families, as well as data on retail store availability. The Florida Citrus Commission and the California Prune Advisory Board will cooperate through September 1960 by providing the contract cost of obtaining the basic data from the Market Research Corporation of America, Chicago. The cost of analysis of data, and publication and distribution of reports, has been provided by the U. S. Department of Agriculture. The program requires about one professional Federal man-year annually.

Progress: Information on household purchases of citrus and competing products is released regularly to growers, processors, and distributors of citrus products, and to marketing, advertising, and research agencies. A monthly series provides current estimates of national volume of purchases, proportion of families buying, size and frequency of purchase, and average prices paid. Quarterly reports present purchase information by regions and retail outlets. An annual summary of these data is made by family characteristics, such as family income, occupation and education of family head, size of family, presence and age of children, and age and employment status of housewife.

A survey of a representative sample of U. S. retail food stores in February 1959 indicated continued expansion in retail availability of chilled orange juice, and a slightly higher level of availability for frozen concentrated juice than in February 1958. Fresh oranges, grapefruit, and lemons were offered by a smaller proportion of stores than in February 1958 with availability of grapefruit lowest for February since 1952. The proportion of stores stocking canned single strength juices, with the exception of lemon juice which was higher, was generally unchanged from a year earlier.

Information was obtained for the first time on the proportion of total grocery sales accounted for by stores stocking each product. This measure showed that all products received a considerably higher exposure to food shoppers than indicated by the proportion of stores stocking and that many citrus products enjoyed almost universal availability.

Information on temperatures of frozen juice cabinets also obtained for the first time indicated that 15 percent of all stores with frozen juice cabinets did not have cabinet temperature indicators. For stores with cabinet temperature indicators, 56 percent were found to have temperature of below 0° F. About four percent of the stores had cabinet temperature of 20° F. and over.

The purchase and availability data have application in the bargaining processes of growers, producers, and distributors of citrus, and in keeping track of changing purchase patterns that have resulted from relatively small crops and shifts in the quantities of citrus fruit utilized for fresh sales and processed products.

Purchase data for fresh lemons, lemon products, and for fresh oranges by area of production were discontinued as of September 30, 1959.

Plans: Reports on household purchases will continue at a somewhat reduced level in the current year compared with the past year, with funds for acquisition of basic data provided by the Florida Citrus Commission and the California Prune Advisory Board. The Department will service the contract, that is, will analyze the data and prepare and distribute reports. Retail store audits of availability of selected citrus products will be continued on a similar basis.

Special analysis of consumer purchase data for fresh oranges and orange products will be started in the current fiscal year. Projections will be developed as to the probable size of the market in 1965 and 1975, and various elasticities of demand will be estimated.

Publications: Consumer Purchases of Selected Fruits and Juices. By Clive E. Johnson. Monthly Consumer Purchases of Fruit Juices Series. (CPFJ)

Consumer Purchases of Selected Fruits and Juices by Regions and Retail Outlets. By Clive E. Johnson. Quarterly CPFJ series. CPFJ-78, March 1959 and CPFJ-82, July 1959.

Consumer Purchases of Selected Fruits and Juices by Family Characteristics. By Clive E. Johnson. Annual CPFJ series. CPFJ-75, July 1959.

Availability of Selected Fruits and Juices in Retail Food Stores. By Robert E. Frye. USDA Consumer Preference Juice Reports, CPJ-71, Aug. 1958 and CPJ-84, Feb. 1959.



## B. Measurement and Evaluation of Market Quality

## OBJECTIVE MEASUREMENT OF MARKET QUALITY FACTORS

BS

Problem: Better methods are needed for measuring quality factors in citrus and subtropical fruits to provide better inspection, grading, and quality control methods.

Program: A continuing long-term program carried out at Orlando and Miami, Florida, and Beltsville, Maryland, including a contract with Industrial Electronic Engineers, North Hollywood, California, for the development of an electronic date moisture sorter, and involving about three professional Federal man-years annually. The Florida Avocado and Lime Commission, Florida Avocado Reserve Trust Fund, Florida Mango Forum, and the Florida Agricultural Experiment Station cooperate in the program.

Progress: Maturity of Murcott Honey oranges. Data continued to be accumulated on changes in fruit weight, juice volume, total soluble solids, total acidity (calculated as citric), ascorbic acid, and pH with age of fruit. These data were taken on 20 groves and included trees growing on three types of rootstocks. Fruit grown on sour orange and Cleopatra Mandarin rootstocks were similar, and the acid content and palatability ratings were higher than that grown on rough lemon. Rind color and palatability increased greatly during December and January, but decreased after March.

Tentative recommendations for minimum maturity standards, based on these data, have been made to the citrus regulatory agencies.

Maturity of Florida avocados. A total of 758 individual avocados, representing six important varieties, were studied for possible maturity indices. The studies included tests for oil content, specific gravity, diameter, flesh color, time required to ripen, and weight loss during ripening. The palatability of fruits from successive harvests was also assayed. Picking of experimental samples began four weeks before the regulated beginning picking date and continued for 12 weeks.

Although oil content increased progressively from the initial sampling date, the variation among individual fruit was so great that oil content could not be used as a criterion of maturity. Changes in specific gravity and color during the maturation period were insufficient to be useful. Fruit diameters and weights coincided with those specified in present maturity standards.

Color and moisture of dates. A second comprehensive experiment to test the capability of several color measurement devices and techniques to measure or indicate color changes in dates was completed.

Color changes were induced by holding dates of different moisture contents at various storage temperatures. A ratio measurement of spectral reflectance at 700/433 mμ was the most useful index of this change. This type of

measurement was done with the IDL Color-Eye instrument. "Rephobiospect" measurements of internal color of the dates showed substantial change at higher storage temperatures. Measurements of internal color change of the intact fruit have the advantage of not being confounded by surface phenomena such as sugar crystallization which may materially affect reflectance measurements.

Color expressions such as dominant wavelength and purity proved less valuable in denoting color changes in the 1958 studies than had been shown in previous work.

A manuscript describing this research has been prepared for publication. The project on color measurement of dates has been completed.

Tests of various methods of rapid moisture measurement indicate that a dielectric loss measurement offers the best possibility for automatic sorting. Laboratory tests with this method showed that moisture content of dates can be determined within an average error of  $\pm 1$  percent. The method can be adapted to high-speed sorting although the error will probably be as high as  $\pm 2$  percent on an automatic machine.

Plans: The research to develop methods for maturity measurement in Murcott Honey oranges will continue for two more seasons, while that on avocados will continue for one more season. Plans for a study of physical and chemical changes of maturing Persian limes have been developed.

Work will be continued on the development of a demonstration model of an automatic machine to sort dates for moisture content.

Publications: Seasonal Changes in Florida Tangelos. By Paul L. Harding, Milliard B. Sunday, and Paul L. Davis. U. S. Dept. Agr. Tech. Bul. 1205, 1959.

#### QUALITY VARIATION AMONG INDIVIDUAL FRUITS IN COMMERCIAL PACKS OF FLORIDA GRAPEFRUIT

BS

Problem: A great deal of variation occurs between individual grapefruit as now packed for shipment. Although the average of the box may meet maturity and other quality standards, some individual fruits are below standard and cause consumer dissatisfaction.

Program: A relatively short-term program of laboratory work conducted at Orlando, Florida, to determine the amount and causes of variation as a basis for improving the uniformity and quality of the fruit and involving less than one professional Federal man-year annually.

Progress: Measurements and analyses were made of 3,800 individual Marsh grapefruits. Wide variations were found in weight, volume of juice, soluble solids, total acid, vitamin C, and solids to acid ratios. Variations in pH

were small. Fruit weight, diameter, volume of juice, and texture of flesh were interrelated. The data suggest that analyses of individual fruit would be preferable to analyses of composited samples of juice. A manuscript on Marsh Grapefruit has been submitted for publication.

Plans: This work will be completed with the publication of a manuscript for the Duncan variety.

### C. Product Protection During Marketing

#### POSTHARVEST PHYSIOLOGY AND STORAGE

BS

Problem: There is need for storage to extend the marketing season to permit more orderly marketing of certain citrus and subtropical fruits. There is also need for a method to predetermine the susceptibility of citrus to rind breakdown so that lots of fruits most subject to this disorder can be processed and fruit least susceptible to rind breakdown marketed as fresh fruit.

Program: This continuing long-term program of basic and applied research is conducted in cooperation with the Florida Experiment Station, the Florida Avocado and Lime Commission, the Florida Industry Reserve Trust Fund, the Refrigeration Research Foundation, and the Crops Research Division, ARS. The work is conducted in Florida, Texas, and California, and involves about four professional Federal man-years annually.

Progress: Predetermining susceptibility to rind breakdown. Several chemical reagents were found to induce rind injury very similar to pitting caused by low temperatures.

A fair correlation has been found between susceptibility to injury by acid and susceptibility to breakdown in storage. Exposing fruit to conditions which favored desiccation such as high temperature, low humidity and high air velocity did not produce typical pitting.

Control of pitting with polyethylene emulsions. Pitting of Florida-grown Marsh grapefruit during refrigerated storage and subsequent holding was reduced substantially by treatment with emulsions of polyethylene before storage. Treated fruit retained normal color and developed no off-flavors or differences in chemical composition. The polyethylene-oleic acid-morpholine emulsion was superior to polyethylene-Tergitol NPX-potassium hydroxide emulsion. A preliminary report has been submitted for publication.

Controlled atmosphere storage. Texas red grapefruit retained its original color, flavor, and chemical composition when stored at 40° and 50° F. in an atmosphere of 2.5 to 5.5 percent O<sub>2</sub> and 2.5 to 4.5 percent CO<sub>2</sub> for six weeks. Good color and flavor was retained at these gas levels



even after removal from 40° storage. At 50° fruit in air faded to an orange color during storage while that in controlled atmosphere faded after removal from storage. Midseason fruit, treated with sodium o-phenylphenate and stored 18 weeks in an atmosphere of 2.5 to 4.0 percent O<sub>2</sub> and 2.5 to 4.0 percent CO<sub>2</sub> at 40° and 50°, developed a high percentage of decay, probably because of high humidity in the CA chambers. The remaining sound fruit were firm and of good color. Flavor was slightly impaired at 40° but not at 50°. External color was retained during storage as well as during a holding period after removal from storage. No consistent differences in internal color were evident in any of the stored samples. External and internal color of fruit picked at the termination of the experiment was considerably faded in comparison with the stored fruit picked 18 weeks earlier. All fruit stored at 33° was unacceptable because of rind breakdown and off-flavors.

Desert lemons stored seven months at 58° F. in atmospheres of 5 percent CO<sub>2</sub> and 3 and 5 percent O<sub>2</sub> remained in generally good condition. Lemons in air were almost fully colored (yellow) in one month at this temperature. Decay and loss of citric acid increased with CO<sub>2</sub> concentrations above 5 percent. Loss of ascorbic acid was influenced in the same manner but to a smaller extent.

Modified atmospheres did not control decay in California desert grapefruit picked during peak of bloom and stored for 2½ months at 40° F. About 30 percent of the fruit in air at 40° pitted, whereas fruit held in modified atmospheres at 40° was pitted much less. That held in air at 56° remained practically free from pitting and decay. The color of the grapefruit held in modified atmosphere at 40° remained an attractive light yellow, whereas the color of fruit held in air, particularly that held at 56°, darkened. The flavor of fruit held under 11 percent CO<sub>2</sub> and 10 percent O<sub>2</sub> was affected but not seriously. The flavor of fruit held under 7 percent CO<sub>2</sub> and 10 percent O<sub>2</sub> was not affected. Acidity decreased more under controlled atmosphere than in air.

Storage of desert lemons. Results of the second year's storage of desert lemons were similar to the first year. Most lots were commercially acceptable after storage for three to four months. Decay averaged three times higher than the previous year, but only one box of fruit had more than 5 percent.

Sensitivity of desert lemons to chilling was studied to determine the effects of subjecting fruit to 40° F. during transit. Dark green lemons were stored 40° for one-half month to correspond with the maximum time for transcontinental transit, and for one month to correspond with the European export schedule. Some fruit was exposed to the chilling temperature before coloring and curing and then held at 58° for a total storage time of as much as five months. Others were cured one and a half months at 58° prior to storage at 40° for one-half and one month, and then returned to 58°. None of the lemons developed symptoms of chilling injury.

Effect of fertilizer on storage life of Florida Grapefruit. Marsh grapefruit from plots receiving high nitrogen, low nitrogen, high potash, and low potash levels of soil fertilization which were stored at 32°, 40°, and 50° F. for six weeks and eight weeks plus an additional seven days at 70° to simulate subsequent marketing, showed no consistent relation of fertilization to pitting and decay. Fruit from all plots developed little or no pitting at 32° or 50°. When stored at 40° pitting developed regardless of fertilization treatment. It was much more severe after eight weeks than after six weeks. Fruit stored at 50° had more decay after six weeks' storage than that stored at 32° or 40°, but decay developed fairly rapidly during the holding period in most samples. The development of pitting and decay is more closely related to storage temperature than to fertilization.

The work on the effects of fertilizer on storage life of grapefruit is completed.

Storage and ripening of Florida avocados. Twelve varieties of avocados were studied. Most varieties ripened normally at 50° to 80° F. Occasionally slight off-flavors developed in fruit ripened at 80° F. Fruits will ripen at 85° F., but quality is very poor. Normal softening does not occur at 90° F. Some varieties will ripen at 45° F., but others are injured at this temperature and do not ripen normally. Fuchs and Winslowson are considerably more susceptible to chilling injury than the other varieties tested, being injured by exposure to a temperature of 50° F. for seven days. For the other varieties tested, the following statements may be made: (1) 50° F. is a safe storage temperature. Fruit will ripen in two and a half to three weeks at this temperature. (2) Avocados may be safely stored at 45° F. for one to one and a half weeks. Longer storage at this temperature may cause chilling injury. (3) At temperatures below 45° F., danger of chilling injury is great in all varieties.

Storage and ripening of Florida mangos. Postharvest behavior of seven principal commercial mango varieties was studied. Mangos ripen normally at 50° to 80° F. Some varieties will ripen at 45° F. 50° F. is the lowest temperature at which mangos may be stored without danger of chilling injury. In most varieties, chilling injury occurs after exposure to 40° F. for five to six days or 35° F. for one to three days. The varieties tested did not ripen normally at 90° F.

Maintaining quality of Persian limes. Further tests were made on the use of the plant growth regulator, 2,4,5-T, as a postharvest treatment on Persian limes. Small beneficial effects were observed in decay control and retardation in loss of green rind color. Butoon retention was strongly promoted by treatment with 1000 ppm. Higher concentrations promoted rind disorders.

Preliminary holding studies at 70° F. were conducted with limes of different sizes. The postharvest behavior of small limes in the 1½ to 1-3/4 inch size range is considerably different from that of larger limes. The small fruits are resistant to decay and tend to remain green for a

long time and become quite hard and poor in quality. Larger fruits gradually turn yellow and eventually decay. The presence of small limes in retail markets is very undesirable because of their slow turnover and consumer dissatisfaction.

Plans: Studies on the storage of desert lemons will probably be completed in another year. Work on predetermining susceptibility to rind disorders will be expanded with emphasis on rind breakdown of oranges which occurs in transit and subsequent marketing. In the CA storage work special attention will be given to control of humidity as this seems to be a factor in decay. The work on storage and ripening of avocados and mangos and the use of polyethylene emulsions on grapefruit will be continued. Studies on limes will be continued.

Publications: Storage Behavior of Lemons from the Desert Areas of Arizona and California. By G. L. Rygg and E. M. Harvey. Marketing Research Rept. No. 310, 1959.

Some Effects of Waxes and 2,4,5-trichlorophenoxyacetic Acid as Postharvest Treatments on Persian Limes. T. T. Hatton, Jr., Proc. Fla. State Hort. Soc. 71: 312-315, 1958.

## POSTHARVEST DISEASES

BS

(See also Maintaining Quality During Transit)

Problem: Effective fungicides and other measures are needed for better control of decay of citrus and other subtropical fruits as they move from the grower through various marketing channels to the ultimate consumer.

Program: A continuing long-term study of basic and applied research conducted at Orlando, Florida; Pomona, California, and Chicago, Illinois, and involving about two professional Federal man-years annually.

Progress: Florida citrus. Six new compounds were screened for control of stem-end rot and green mold in oranges at Orlando. None were effective. Large scale chemical screening tests for citrus have been completed.

Fifteen of the most promising compounds obtained through the screening program in the last ten years were re-evaluated this season on a larger scale. These compounds used as a 2-minute dip followed by a tap water spray rinse were compared with Dowicide A plus Hexamine. They were tested on naturally infected early, midseason, and late varieties of oranges. Carbanilic acid, m-chloro-isopropyl ester; Hydra-crylonitrile, carbanilate; and 2-Propyn-1-ol-carbanilate gave good results as a postharvest dip and when incorporated in a water emulsion wax.



Florida mangos. Two exploratory experiments were conducted on post-harvest diseases of mangos with particular emphasis on anthracnose. Various hot water treatments gave relatively good results. Treatment for 10-20 minutes at 125° F. delayed development of anthracnose for approximately five days and reduced stem-end rot. Slight scalding was observed on several fruit. Due to the unusually short harvest season these tests could not be repeated or further exploited. The big advantage of hot water treatment is the absence of fungicidal residue. Hot water apparently has no adverse effects on natural ripening or subsequent flavor. Chemical treatments, including Dowicide A plus Hexamine were relatively ineffective.

Radiation treatments. The failure of irradiation to retard or control blue mold rot of oranges in commercial packs, led to the elucidation of some responsible factors. The rate of gamma flux, which was 10 to 60 times slower than in laboratory scale experiments, was found to influence both the rate and the total incidence of decay. In three separate experiments, there were no differences in decay at doses of 68,000 rad and 90,000 rad at fast or slow rate of flux. However, in each instance at doses of 125,000 to 182,000 rad, a fast flux (8,000, 20,000, or 40,000 rad/min.) retarded the rate and total incidence of fruit decay better than a slow flux (3,000 rad/min.) A rate of flux of 40,000 rad/min. was most effective.

Plans: Promising materials will be further tested. Work with mangos will be continued. Irradiation research will be continued.

Publications: Factors Influencing the Use of Gamma Radiation to Control Decay of Lemons and Oranges. L. Beraha, G. B. Ramsey, M. A. Smith, and W. R. Wright. Phytopath. 49: 91-96. 1959.

Biphenyl-induced Variations in Citrus Blue Mold. Paul R. Harding, Jr., Plant Disease Reporter 43, No. 6, pp. 649-653.

Relative Humidity in Citrus Cartons as Influenced by External Temperature and Relative Humidity. Paul R. Harding, Jr. Plant Disease Reporter 43, No. 8, pp. 893-897.

## MAINTAINING QUALITY DURING TRANSIT

BS

Problem: With the adoption of new containers and new types of rail and truck equipment, there is need for information on methods of loading and refrigeration to protect citrus fruits from spoilage in transit and subsequent marketing.

Program: A continuing program of precooling and shipping tests conducted in cooperation with the Florida, California, and Hawaii Experiment Stations, growers, shippers, carriers and receivers at Orlando, Florida; Pomona, California; Harlingen, Texas; New York, N. Y., and Chicago, Illinois, and involving about three professional Federal man-years annually.

Progress: Hydrocooling of Florida citrus. Shipping tests were conducted on hydrocooled oranges packed in 5-pound vented polyethylene bags in master cartons and nonhydrocooled oranges in 5-pound mesh bags in wirebound crates. There was about twice as much decay in lots hydrocooled in plain ice water as in those receiving no treatment when held at 70° F. for seven days after arrival. The use of 1,000 ppm. sodium-o-phenylphenate (Dowicide A) in the hydrocooling water reduced the decay by more than half. Double treatments involving the use of 101-A wax (emulsion wax containing Dowicide A plus Hexamine) or biphenyl pads in addition to sodium-o-phenylphenate in the water was in general better than the single treatment. Rind breakdown was insignificant in all treatments. The appearance of the hydrocooled fruit in polyethylene bags was slightly better on arrival at New York City than the nonhydrocooled fruit in mesh bags, probably because of less water loss. Hydrocooling in plain ice water was detrimental to shelf life of citrus. All commercial operations use 1,000 ppm. sodium-o-phenylphenate in the hydrocooling water.

Load patterns for wirebound crates. Three different loading patterns were tested during 1959 to determine their effects on rate of cooling and market quality of oranges. The fruit was packed in 4/5-bushel Baby Bruce (wirebound) wooden containers and shipped by rail in end bunker fan cars from Mims, Florida, to New York City. The commodity temperature and the rate of cooling of the fruit were greatly influenced by load pattern. Lower average commodity temperatures were obtained in the space bonded block and the channel load as a result of opening up the load and channeling of cool air within the car, particularly at the middle quarterlength position. Higher temperatures were obtained when the containers of fruit were loaded according to the conventional double off-set pattern. Inspection at destination indicated no outstanding effects from load patterns on market quality of oranges or condition of containers and load.

Ventilation of cartons on cooling rate. At the request of several shippers in the Indian River League, rail shipping tests were made during May and June 1959, from Florida to New York City to compare cartons with two side slots with those having three side slots. The results showed only slight differences in the rate of cooling. Commodity temperatures were about the same at the bottom bunker position in the two kinds of cartons. At the middle quarterlength position, commodity temperatures were one to 3 degrees cooler during transit in the three slot cartons than in the two slot cartons. However, this slightly lower temperature was not reflected in market quality of the fruit. No severe rind breakdown was observed upon arrival or after seven days at 70°.

Truck-Rail (piggy-back) tests. Truck-rail shipping tests were continued to obtain further information on the influence of load pattern, load weight, type of container, and packaging on the load temperature during transit in mechanically refrigerated trailers. The test loads which originated in the Lower Rio Grande Valley of Texas included prepackaged oranges in master cartons and grapefruit in 1/2-box cartons. The load patterns varied from solid to open.



The results confirmed that the rate of cooling is limited by the load pattern, type of container, and packaging. Apparently the capacity of the refrigeration unit is sufficient to compensate for differences in load weights and commodity temperatures at time of loading. The air temperature within the trailer cooled to the thermostat setting in six to 48 hours, after which the unit and fan remained inactivated for the balance of the trip (30 to 96 hours). However, the commodity temperature at the time the unit cut off was three to 21 degrees warmer than the air temperature. During the remainder of the trip the commodity temperature followed the outside air temperature. For example, one load shipped in November cooled 13 degrees while another shipped in May warmed six degrees. A solid (non-channeled) load of prepackaged warm oranges in master cartons cooled very slowly. Well-channeled loads cooled well.

The work on truck-rail (piggy-back) services and studies comparing two versus three side slots in citrus containers is completed.

Shipment of Hawaiian papayas. Three test shipments of papayas from Hawaii were received at Pomona. Ethylene dibromide plus hot water treatment was compared with vapor heat. No substantial difference in effect of the treatments was observed. Papayas shipped at 47° ripened satisfactorily in transit or after arrival. Ripe fruit shipped at 32° arrived in excellent condition and remained in relatively good condition for one week at 76°. No noticeable impairment of flavor or appearance developed as a result of the 32° transit temperature, whereas some protection from decay was realized. Chilling injury occurred in unripe fruit.

Plans: Studies on hydrocooling, load patterns, and on shipments of Hawaiian-grown fruit will be continued. Export studies of California citrus are under way.

## PROTECTION OF DRIED CITRUS PULP AGAINST INSECT INFESTATION

BS

Problem: Effective methods are needed for controlling and preventing insect infestation of dried citrus pulp animal feed while in storage. Because animal feed is considered a processed food, the treatments developed must leave no residues which will be objectionable according to the requirements of the Food Additive Amendment to the Food, Drug, and Cosmetic Act.

Program: This is a continuing long-range program of basic and applied research on the development of control and preventive measures for insects attacking stored processed foods and is conducted at Savannah, Georgia, in cooperation with the industry. It involves two professional Federal man-years annually.

Progress: Large-scale field tests have shown that a synergized pyrethrum wettable powder spray applied monthly to the surface of stacked bagged feed at the rate of 5 mg. of pyrethrins per square foot of surface will provide a high degree of protection against insect infestation. A test presently under way shows that a malathion wettable powder spray applied in the same



manner at 75 to 150 mg. of malathion per square foot gives better protection than synergized pyrethrum and is effective against more insect species. The chemical and biological data being collected in this test will be used to request label approval and petition for tolerances for both pyrethrum and malathion.

Plans: The field tests now under way will be completed this year. Additional work on the protection of dried citrus pulp will depend largely on the results of this year's test and the action by the Food and Drug Administration on the petitions for tolerances on pyrethrum and malathion.

Publications: Protection of Citrus Pulp Against Insect Infestation with Surface Applications of Pyrethrum-piperonyl Butoxide Wettable Powder. H. Laudani, Hagen B. Gillenwater, Ben H. Kantack, and Margaret Phillips. Jour. Econ. Ent. 52(2): 224-227. April 1959.

#### D. Equipment, Facilities, Methods, and Firm Efficiency

##### IMPROVED METHODS, EQUIPMENT, PLANT LAYOUT AND DESIGN FOR HANDLING AND PACKING CITRUS FRUIT

TF, OC, AE

Problem: Growers and packinghouse operators need information on more efficient methods, devices, and equipment, and the design of improved facilities for handling, precooling, degreening, and preparation for market of fresh citrus fruits at shipping points.

Program: This continuing long-range program of engineering and economic research is carried on in Florida by field offices located at Gainesville, Florida, and Athens, Georgia, in laboratory facilities of the University of Florida at Gainesville and Lake Alfred and in privately-owned citrus packinghouses; in cooperation with the Florida Agricultural Experiment Station, and the Agricultural Research Service; at a rate of three professional Federal man-years annually.

Progress: Handling. Cooperative arrangements were developed for testing the use of large pallet boxes for handling fresh citrus from the picker to the packing line. A Memorandum of Understanding covering this work was negotiated between a commercial citrus packinghouse, the Florida Agricultural Experiment Station, the Agricultural Research Service, and the Agricultural Marketing Service. Five different types of pallet boxes were designed for this experiment and orders placed for 20 boxes of each type.

Degreening. Oranges were degreened experimentally in five types of pallet boxes at the Citrus Experiment Station in collaboration with State research workers. Four of these types were commercially available boxes having a capacity of about 1,200 pounds of fruit. The fifth type was a one-ton box used by a Florida packinghouse. Degreening results obtained with these boxes were compared with those obtained on control lots of fruit degreened in conventional field boxes. Preliminary findings were that citrus fruit will degreen as well in large boxes as in the standard field box stacked four high, when other conditions are comparable. Differences in the packout between fruit degreened in field boxes and that degreened in each of

the different pallet boxes were not significant. The one-ton box had slatted sides and bottom. Other boxes included these variations: Slatted sides and bottom, slatted sides and solid bottom, solid sides and slatted bottom, and solid sides and bottom.

Precooling. Work on precooling citrus fruits was limited to the negotiation of an agreement between the Florida Agricultural Experiment Station and the Agricultural Marketing Service on cooperative work to be initiated during the fall of 1959.

Preparation for market. Tests of an experimental transverse drop-roll type sizer used for the first year in one citrus packinghouse showed the following results: (1) Fruit should be delivered to this sizer from a roller belt of the same effective width as the sizer for proper placement of fruit on the sizer rolls in order to increase the accuracy of sizing and utilize the full capacity of the equipment; (2) the direction of rotation of the fruit should be maintained as it passes from the feeding mechanism or to the sizer rolls; (3) sizer rolls should rotate at sufficient speed to cause fruit to rotate about its stem-blossom axis, the diameter around which fruit must be sized to meet official standards. Studies to compare the accuracy of different types of sizing equipment now in use were continued. Statistical analysis of data obtained was started but final results are not yet available. However preliminary observations indicate there is no distinct difference in sizing performance with different belt speeds or roll speeds on belt-and-roll type sizers.

A roll-board packing station was designed, two installations were made in commercial packinghouses, and tests were made under commercial conditions. The roll-board which replaces the conventional bin as an accumulator-packing station provides an improved method of getting the fruit to the packer and in the layout of conveyor line for moving packed fruit away from packing stations. The new roll-board station made possible a significant reduction in packing time. A manuscript covering results of the tests of this roll-board type packing station is about 90 percent completed.

Costs. Two bulletins were published, the conclusions of which were reported in previous progress reports. One deals with economies of scale in handling and packing citrus fruits and the other with the relative costs of different methods for performing a number of specific packinghouse jobs.

Plans: Tests of the handling and degreening of citrus fruits from the picker to the packing line in large pallet boxes will begin with the 1959-60 citrus season and are expected to continue for about three years. Citrus sizing studies will be continued.

An engineering-economic analysis of representative "shaker pack" methods and suitable recommendations for the application of this method will be initiated.

A study will be undertaken to determine the relative costs of handling Florida citrus fruits from the grove onto the packing line in large pallet boxes, as compared with conventional field boxes and the bulk method.

Earlier work has compared costs for the bulk and field box methods. These data will be brought up to date in terms of current prices and wages. Data will be collected on the operation of an experimental pallet box operation to be used to compare costs for the three handling methods.

Work on an engineering-economic study of a "two-stage" citrus packinghouse operation (fruit held temporarily after sizing and packed in sizes as ordered) also will be initiated to determine possibilities for increased efficiency in packing and in the cleaning-sorting-sizing and precooling operations.

Attention will be given to improving the roll-board packing method and to adapting this method for manually filling small bags with fruit.

Automatic closing machines for wirebound boxes will be evaluated to determine their effect on costs, handling of packed boxes, and on the plant layout.

Attention also will be given to the sorting operation to find practical possibilities for increasing labor efficiency.

Publications: Degreening Citrus Fruits in Large Pallet Boxes. G. E. Yost, E. K. Bowman, W. Grierson, and F. W. Hayward. Citrus Magazine, May 1959, and Agricultural Marketing Vol. 4, No. 5, May 1959.

Economies of Scale in the Operation of Florida Citrus Packinghouses. Eric Thor, Florida Agricultural Experiment Station Bulletin 606, Jan. 1959.

Comparative Costs of Alternative Methods for Performing Certain Handling Operations in Florida Citrus Packinghouses. George L. Capel, Florida Agricultural Experiment Station Bulletin 609, June 1959.

## E. Costs, Margins, and Organization of the Marketing System

### CHANGES IN METHODS OF MARKETING

OC

Problem: Citrus industry leaders need more accurate information on the changes taking place in wholesale markets for citrus fruits and other fruits and vegetables in order to evaluate the impacts of these changes on the industry and to assist in making decisions and recommendations for adjustments to meet these changes.

Program: A three to four year research program surveying 20 to 30 principal markets and involving about four professional man-years annually. This program is being carried out from the Washington Office with participation from Agricultural Experiment Stations in New York, West Virginia, Kentucky, Wisconsin, Oregon, Maine, and Oklahoma, and through contract studies in the San Francisco market area by the University of California and in Pittsburgh by Midwest Research Institute.



Progress: A study of auction markets was completed and published. Changes in the pattern of fruit marketing beginning in the late thirties and accentuating since World War II have altered the role and importance of the fruit auctions. Auction sales of citrus declined from 36 percent of total fresh market sales during the 1935-36 season to about 16 percent in the 1955-56 and 1956-57 seasons. The auctions sold over three-fourths of the citrus received in cities having auctions in 1930. In 1956-57, the share had declined to about half.

Sharp increases have occurred in direct buying by retailer groups--both corporate and voluntary chains--and, to some extent, by service wholesalers and other types of wholesale handlers. The number of retailer groups large enough to take advantage of direct buying has grown until they now handle a major portion of the retail food business.

More and more, the fruit auctions are becoming distributors of higher-priced specialty products rather than mass distributors of more standardized fruits.

Field work is now under way for a study of the present status and organization of approximately 20 wholesale fruit and vegetable markets throughout the country. This information will provide the basis for description of the wholesale markets and analysis of the role of terminal markets in the years ahead.

Plans: The survey work will continue and the preparation of reports will begin as soon as possible.

Publications: The Changing Role of the Fruit Auctions. Alden C. Manchester, USDA, MRR-331, June 1959.

## MARKETING CALIFORNIA DATES

OC

Problem: Date growers and packers need information on the relative costs of different methods of performing specific packinghouse operations to assist them in adopting methods which will lower costs. Information also is needed on industry organization and prospects to assist them in adjusting to changing market conditions.

Program: A two-year applied study involving less than one Federal man-year of personnel of the Washington and Los Angeles offices and a contract with Midwest Research Institute for the survey and analysis of the cost and efficiency in packing dates.

Progress: Three of the 31 packinghouses in the industry packed over 70 percent of the crop during the 1956-57 season. An additional 15 packinghouses packed another 20 percent. The three largest packinghouses packed

the majority of the retail-size packages and all of the pitted dates. They also made almost all of the industry's expenditures for advertising and promotion.

Chainstores were the biggest sales outlet for dates, taking 50 percent of the 1956-57 sales. Produce wholesalers and specialty wholesalers took an additional 25 percent. Over one-half the sales were made through brokers. Packers have found it necessary to maintain larger stocks of dates in the market areas than previously.

Plans: The results of these studies will be published during the coming year.

## IMPROVING COORDINATION AND DISTRIBUTION METHODS

FCS

Problem: Changing marketing conditions require improved methods for the coordination and distribution of fruit to meet the needs of large-scale buyers, as well as to improve the competitive position of growers in a mass-distribution system. Basic economic information is needed to assist in making marketing decisions which will reduce costs, increase sales, maximize returns and meet the needs of the market.

Program: This continuing long-range program of applied research is conducted in major producing areas and is contributing to Southern Regional Citrus Marketing Project SM-22. It involves about two professional Federal man-years annually.

Progress: Coordinated selling of fresh citrus fruit in Florida. The phase of this work concerned with sales practices and pricing policies has been completed this year with the publication of two reports. An analysis of returns and practices of Florida citrus sales organizations, previously reported on, is described in Marketing Research Report 345. A statistical summary of distribution patterns of fresh citrus shipments of the packinghouses cooperating in the study have been made available in FCS Service Report 46.

Another phase of this work is concerned with the need and feasibility for developing a joint marketing program for Florida fresh citrus fruit. Although analysis has not yet progressed sufficiently to comment on findings, it is well enough along that a preliminary report is scheduled for October 1959. This report will be concerned with key questions asked of substantially all Florida shippers handling in excess of 100,000 boxes of fresh citrus fruit annually.

Marketing program for Florida avocados and limes. The draft of the report on this study has been revised in the light of recent weather and economic impacts on the Florida lime and avocado industry. Based on study findings, the report recommends that a more perfectly coordinated marketing program for the industry can be achieved by: (1) More intensive application of existing coordinating elements; and (2) sale of the two products through a single marketing agency.

Plans: Immediate plans are to complete the analysis of the need and feasibility for developing a joint marketing program for Florida fresh citrus fruit. A final report on this work is to be completed in the spring of 1960.

As a next step an examination will be made of direct selling and direct procurement methods as they affect coordinated marketing of Florida fresh citrus fruit. These marketing methods are accounting for an increasingly largeshare of the volume of Florida citrus fruit and all other fresh fruits and vegetables marketed. Their effect on increasing or limiting



marketing coverage, specification order problems, and industry growth generally will be examined with particular emphasis on returns to the grower.

Publication of a report will complete the avocado and lime study.

Publications: Analysis of Returns and Practices of Florida Fresh Citrus Sales Organizations. Fred E. Hulse, Marketing Research Report 345, June 1959.

Distribution of Fresh Citrus Shipments by 38 Florida Packinghouses in 1953-54. Fred E. Hulse, FCS Service Report No. 46, June 1959.

Marketing Adjustments Made by the Texas Citrus Industry to Freezes of 1949 and 1951. Wilbur F. Buck and Harold B. Sorensen, Marketing Research Report 328, June 1959.

#### IMPROVED PRICING METHODS

FCS

Problem: Improved pricing plans and grower payment methods are needed to more accurately reflect changing market requirements back to growers and grower organizations so as to better balance supplies with demand. Changing industry organization and procurement practices required by mass distribution are bringing about more complex product specifications, and has altered pricing techniques which reduce the effectiveness of conventional pricing methods.

Program: This continuing long-range program of applied research, part of which is contributing to the Western Regional Project WM-38, is conducted in major production areas and involves about two professional Federal man-years annually.

Progress: Improving pooling and payment practices for producers. A report has been completed and submitted for publication. It was found that citrus and subtropical fruit cooperatives, like other associations using a pooling method for paying growers, were in the best position to capitalize on the changing market structure. In contrast to those handling products as individual lots, these cooperatives handled a greater number of commodities, offered more services to their members, had the greatest opportunity for developing an orderly marketing program, and relied more heavily upon a grower-member contract to integrate the production practices of growers with their association's marketing requirements. By handling a greater number of commodities, pooling cooperatives provided more product diversification; by providing a complete set of marketing services, they more fully utilized alternative marketing outlets; and by relying more heavily upon cooperative marketing contracts, they were assured of more stable supplies upon which to develop a sounder sales program.

Fruit and Vegetable Bargaining Cooperatives. Building on information obtained in the first phase of this study (which was reported in FCS Circular 25), preliminary work is under way to analyze the impact of bargaining associations on the structure and behavior of the fruit and vegetable processing industry, measuring such effects as amounts paid for raw product as well as in other contract terms; and their influence on scale of operations and on the trend toward vertical integration.

Again at the request of growers, a Third National Conference on Fruit and Vegetable Bargaining Cooperatives was arranged and conducted by Farmer Cooperative Service in January 1959 in New Orleans. A proceedings of the conference, which included findings from this study, was prepared and distributed. A regional conference, with proceedings, was also held for Eastern and Mid-Western Bargaining Associations at the University of Illinois in August 1959.

Plans: The work on grower payment methods involve a comparison of returns to growers of selected fruits and vegetables among various grower payment plans highlighted in the first phase, and collection and analysis of data on the impact of bargaining associations will be undertaken as the second phase. Publications are planned for each area of study.

Publications: Pooling and Other Grower Payment Methods as Used by Local Fruit, Vegetable, and Tree Nut Cooperatives. Clyde B. Markeson, FCS, General Report 67, Oct. 1959.

Proceedings of the Third National Conference on Fruit and Vegetable Bargaining Cooperatives, FCS Unnumbered Report, Jan. 1959.

Bargaining Cooperatives Pay Off. Agricultural Research, March 1959.

Interest Grows in Fruit and Vegetable Bargaining Cooperatives. W. M. McMillan. News for Farmer Cooperatives, March 1959 (also Reprint 168).

Proceedings of the Regional Conference of Eastern and Mid-Western Fruit and Vegetable Bargaining Cooperatives. FCS Unnumbered Report, Aug. 1959.

## F. Price, Supply, and Consumption Analysis

DEMAND, OUTLOOK AND SITUATION ANALYSES FOR CITRUS AND  
SUBTROPICAL FRUITS

AEC

Problem: Producers, processors, distributors, and consumers need information on past and probable future production and consumption of citrus and subtropical fruit and the effect of these and other factors on price.

Program: Continuing statistical analysis of data and preparation of periodic situation and outlook reports, supplemented from time to time with special statistical studies of factors that affect demand and price, using data assembled by census and agricultural estimates, and other agencies, carried on in Washington, D. C., and involving one professional man-year annually.

Progress: Situation and outlook work has continued with regularly scheduled reports of The Fruit Situation, The Demand and Price Situation, and The National Food Situation. A special article in The Fruit Situation, January 1959 showed that regional differences in the use of purchased fruit were small except in the South, and that urban households bought more fruit than farm households but that home-grown fruit on farms more than made up the difference. Households bought on the average about 15 percent more citrus than noncitrus fruit. Another special article in the August 1959 issue showed that value of fruit and fruit juice deliveries in schools having food service was about \$36 million, or an average of \$1.70 per child, in the year ending June 1958. Fruit juice consumption was relatively minor compared with fruits. Orange juice accounted for three-fourths of the total fruit juice.

An economic analysis of the demand for lemons and lemon products is just getting under way. It will examine the problems connected with the growing importance of concentrate for lemonade, the larger crops of lemons, and production of lemons in new areas. The effects of imports of frozen concentrated lemon juice on the market for lemons and lemon products also will be evaluated.

Plans: Continue regular analyses and the issuance of situation reports, and to complete the analysis of the demand for lemons and lemon products.

Publications: The Fruit Situation is published four times a year, with a comprehensive outlook report in the October issue.

The Demand and Price Situation is published monthly and includes a summary on the price situation for fruit.

The National Food Situation is published quarterly and includes a summary of supply and consumption of fruit.

Fruit Consumption of Households, by Region, Urbanization Group and Income, Thos. J. Lanaham, Jr., and Ben H. Pubols, Fruit Situation (TFS-130). Jan. 1959

The Market for Fruits and Fruit Juices in Public Schools, Kenneth E. Anderson and William S. Hoofnagle, Fruit Situation (TFS-132). Aug. 1959.



